Popular Astronomy

Vol. LI, No. 6 **JUNE, 1943** **Whole No. 506**

Copernicus and Modern Revolutions*

By JOEL STEBBINS

We are in the midst of centennials. Last year we had the anniversaries of the death of Galileo and the birth of Newton, this year it is the death of Copernicus. Considering the sequence of Copernicus, Tycho, Kepler, Galileo, and Newton, if we celebrate both the birth and the death of each one we shall have ten anniversaries per century, or even more if we put in the fifty year intervals. Yet among these possibilities the one date that seems to stand out above all others is 1543; this was the beginning, the zero epoch. We may not remember when Copernicus was born, but we do remember the date of the publication of *De Revolutionibus Orbium Coelestium*. The immortal life began at seventy for Copernicus.

The circumstances of the change from the Ptolemaic to the Copernican System are so well known that it is superfluous even to mention them. It may be of some interest, however, at a time like this to recall some of the earlier suggestions of the heliocentric system back in the days of the Greeks. I, myself, have never been able to form a clear idea of the conception of the universe which was held at any definite time by a particular authority or by a large number of intelligent people. I should like to see prepared a large double entry table with headings at the top containing items like this. For the Earth, in different columns, its nature, shape, size, rotation, revolution. For the Moon, the same items and also the cause of the phases. For the Sun, its nature, the source of its energy, and its motion. For each of the planets, its distance, or the sizes of the deferent and the epicycle. For comets, their nature and motions. For the stars, whether they are self-luminous or merely holes punched in an opaque shell.

At the left side of this table could be arranged the great names of science beginning with the earliest and, in chronological order, those down to the present time. Thus, opposite each name one could trace horizontally in the table the best thought of the corresponding time, while in each vertical column the changing ideas on each subject would fall in a historical sequence. It would be a large table and there would be many blank spaces, some with question marks, and the most frequent positive entry might be "Confused."

To illustrate the idea we might begin with Thales (*c.* 600 B.C.) at

*Adapted from addresses at a convocation of Indiana University and at the meeting of the American Astronomical Society, May, 1943.

the upper left and tracing his line we find at once that the Earth was a flat disk floating on water. Other entries would be opposite Pythagoras or the Pythagoreans (*c.* 500 B.C.), the Earth a sphere and rotating but about an external axis. And so we could trace through the Greeks the development or rejection of the simple concepts which have come down to us. Opposite the great name of Aristotle (384-322 B.C.) there is the spherical Earth but it was fixed both as to rotation and revolution. Preceding Aristotle we have the crystal spheres of Eudoxus (366 B.C.) which lasted through to Hipparchus and Ptolemy and then on for nearly 1900 years from their inception. The first positive entries of the rotation and revolution of the Earth are found opposite Aristarchus of Samos (*c.* 310-230 B.C.). But Aristarchus was far ahead of his time, about 1700 years to be exact. Opposite the names of Hipparchus (130 B.C.) and Ptolemy (140 A.D.) as you know, our table could be pretty well filled in. Their ideas were definite and can be written down without question marks.

If the table is arranged with the vertical spaces proportional to the time, there is the congestion of the names during the time of the Greeks, many names in the 400 years between Pythagoras and Hipparchus, then a gap of 250 years between Hipparchus and Ptolemy in which no name of importance appears. We then have the long space of 1400 years to be left practically blank on the chart. It may be left blank or filled in as dark if you choose. Then again is the concentration of names, Copernicus, Tycho, Kepler, Galileo, and Newton. They are bunched into less than 150 years between the appearance of *De Revolutionibus* in 1543 and the *Principia* in 1687. From Newton to the present there is nothing to add to the main features of the table, only details. The solar system remains as Copernicus resurrected it and as Newton perfected it. The great development in the region of the stars made possible by the invention of the telescope and the application of all the resources of modern science runs us off the chart. We would need more paper and an enlarged scale to get everything in.

All this is certainly over simplification. You can not put the development of the human race or even of astronomy on one page, but no matter how the picture is drawn the name Copernicus stands out at the discontinuity between the old and the new. There may have been only one system of the world for Newton to discover, but it was Copernicus who showed the way.

The work of Copernicus loses none of its interest when considered in relation to the time in which he lived.[1] He was born of a wealthy family but his father died early and when Copernicus was ten years old he was placed, with a sister and brother, under the guardianship of his uncle, Lucas Watzelrode, Bishop of Warmia, a man of great power and

[1] I am indebted to my colleague, Dr. Edmund Zawacki of the department of Polish of the University of Wisconsin, for some of these historical items.

influence. There was probably nothing unusual in the early education of Copernicus in the parish and cathedral schools in preparation for the university. At the time of his birth the University of Krakow was already more than 100 years old. It was the first university north of the Alps to take a friendly interest in Italian humanism. In Poland, as elsewhere in Europe, most of the exact sciences were still in their infancy. The chief glories of the University of Krakow were considered by some to be the chairs of astronomy and of astrology. There was an endowed chair of astronomy as early as 1406, nearly a hundred years before the next such chair in Central Europe. The study of astrology was similarly established at about 1450 on funds provided in the will of the astronomer, Marcin Krol. For a long time, even after Copernicus, the two sciences were closely related. Astronomy, indeed, was regarded merely as "theoretical astrology" and the failures of astrological predictions were attributed to the imperfections of astronomy. We of the present would be quite suspicious of instruction in astronomy so closely allied to astrology. It seems, however, that Albert Brudzewski, the teacher of Copernicus in astronomy was rather critical in his exposition of the Ptolemaic system, and while it is impossible to say how far Brudzewski influenced Copernicus in favor of the heliocentric theory he undoubtedly started Copernicus to thinking seriously about the nature of the world.

In addition to astronomy and mathematics Copernicus naturally spent much time on the classics, but he found opportunity to study drawing and painting for his own pleasure. After four years at Krakow he was obliged to leave. His uncle, the bishop, had made him a canon of the cathedral chapter in Warmia, and by direction of his uncle he made his way to Italy to study law at Bologna. All told he was about eight years in Italy, during which time he did something with mathematics and astronomy, but he also took up medicine and received a medical degree at Padua in 1503 and in canon law at Ferrara the same year.

Thus after a dozen years of study he was ready, on his return to Poland, for the quiet life of a churchman. Circumstances forced him to take part in military operations and he became commander-in-chief of the defense of Warmia, and, in particular, he directed a successful defense of the city of Allenstein against the Teutonic Knights. To the titles of churchman, physician, astronomer, and soldier, we must also add that of economist. Copernicus wrote a treatise on coinage, and as administrator of the church lands in Warmia he compiled a sliding scale of ceiling prices for bread based upon the varying local prices of grain. He also reformed the weights and measures throughout the area under his jurisdiction.

We see that astronomy was only one of the activities of the many sided Copernicus. He seems to have carried on his studies quietly by himself with little influence from colleagues or disciples. He had no dif-

ficulties with opposition in the church. In fact, the friend who most eagerly urged him to publish and who actually undertook the expense of printing was a cardinal, and when *De Revolutionibus* appeared it was dedicated to Pope Paul III. It was Galileo, a century later, who got into difficulties over his vigorous espousal of the Copernican system. With Copernicus it was "take it or leave it" and for himself it was to leave it, for only by a narrow margin in time was the printing of the book completed before his death.

The slow adoption of the Copernican system was characteristic of all countries. In America the Ptolemaic and Copernican systems were taught concurrently at Harvard and also at Yale. The exact date of the beginning of Harvard College is not clear but it was not later than 1640 or two years before the birth of Newton. By the time of the publication of the *Principia* in 1687 there probably was not much left of the Ptolemaic system. It is interesting to note what Newton himself said about the crystal spheres supporting the planets. In the introduction to the System of the World in the third volume of the *Principia* he says:

"But above all things the phenomena of comets can by no means consist with the notion of solid orbs. The Chaldeans, the most learned astronomers of their age, looked upon the comets (which of antient times before had been numbered among the celestial bodies) as a particular sort of planets, which, describing very eccentric orbits, presented themselves to our view only by turns, *viz.*, once in a revolution, when they descended into the lower parts of their orbits.

"And as it was the unavoidable consequence of the hypothesis of solid orbs, while it prevailed, that the comets should be thrust down below the Moon, so no sooner had the later observations of astronomers restored the comets to their antient places in the higher heavens, but these celestial spaces were at once cleared of the incumbrance of solid orbs, which by these observations were broke into pieces, and discarded forever."

For the physical proofs of the Earth's motion around the Sun the textbooks usually give, (1) the aberration of light, (2) the annual parallax of the fixed stars, and (3) the annual displacement of the spectral lines of the stars. To these might be added, (4) the annual shift in the phases of periodic variable stars. We have many tables for the light equation, "heliocentric minus geocentric time," but somehow this effect is not usually mentioned as a proof of the Earth's motion about the Sun. If the phases of a rapidly changing eclipsing star are determined with a probable error of one minute at different times of the year, the material is at hand for a rough demonstration of the revolution of the Earth, and this without the precise but laborious observations of the other methods.

We in our time have also been passing throught a change just as revolutionary and perhaps as little noticed as when the Polish churchman

quietly jolted us out of our fixed and privileged position at the center of the universe. Whereas for Copernicus the question was mainly whether the Earth or the Sun was at the center of the solar system, for us the questions have been whether the Sun is near the center of the galaxy, how large is the galaxy, and are there other galaxies besides our own?

Less than twenty-five years ago, in the year 1920, there was a famous public astronomical debate in the city of Washington. The contestants were Harlow Shapley and Heber D. Curtis. The question at issue was the Scale of the Universe, which was resolved into two main points, first how large is the galaxy, and second are the spiral nebulae independent external systems of stars? Concerning the first point, the issue was quite definite, one side argued for a diameter of the galaxy of 300,000 light years, the other side for 30,000 light years, a disagreement of ten to one. Concerning the plurality of galaxies, the first side held the view that the galaxy is large enough to contain everything in sight, including the spirals. The other side maintained that the spiral and elliptical nebulae are not in our galaxy but are extra-galactic systems, each composed of many stars.

In the twenty odd years since that debate astronomers have come to a reasonable agreement on the questions at issue. We shall not try to name the individual investigators who have contributed to the solution of the problem, it is the name of Copernicus which is before us now. The size of the galaxy has been settled by a compromise. If we divide the 300,000 light years by three, or multiply the 30,000 light years by three, we get roughly 100,000 light years, or 30,000 parsecs, which is not far from the present accepted diameter of the galaxy, though some would prefer 40,000 parsecs. At the meeting of the International Astronomical Union at Harvard in 1932 there seemed to be agreement or even complaint that "the galaxy is too large." Since that time the allowance for interstellar absorption has helped to decrease the estimated size of the galaxy, though as more and more outlying stars are discovered it is difficult to hold the galaxy to dimensions comparable with other systems.

That there are other systems is now acknowledged by the general acceptance of the term "extragalactic nebulae." The measures of their spectra and the identification in them of individual stars such as Cepheids and other giant stars and novae, as well as clusters, has given a fascinating chapter to the story which Copernicus began when he moved the Earth out of the center of things. But whenever we mention Copernicus we think of the question of how bodies are rotating or revolving. Curiously, the nature and directions of the rotation of the galaxy was settled before agreement could be reached on the spirals which are right out before us to see. However, the figure of 200,000 years for the Sun's period about the galactic center rather dampens our enthusiasm for waiting for differential proper motions to reveal the

rotations of the nebulae. The measures of radial velocity in different parts of a nebula give results more quickly, but even here, as you know, we were in for some surprises.

A layman would probably smile if he could have heard some of the discussions among modern astronomers, even in the last five years, as to the direction of rotation of the spiral nebulae. If the ancients were wrong in having the Sun revolve about the Earth, they at least had the direction of its motion right. Yet only recently, although astronomers were quite agreed that the spirals must be in rotation, the sense of the rotation, whether a spiral was winding or unwinding was in doubt. I do not need to remind you of the cause of the uncertainty, that the inclination of a nebula may be just as indeterminate as the inclination of the orbit of a double star; and even when dark lanes exist across the surface of a nebula it is not always easy to tell which is the near side. The definite answer seems to have come in the past month, in a paper in the last *Astrophysical Journal*. In fifteen spirals the rotation is in the sense that the inner parts move faster than the outer ones, in other words, the arms are trailing behind the nuclear regions.

So at last the work of Copernicus has been brought to completion. We have the fundamental motions of the Earth, the Sun, our galaxy, and the other galaxies. In asserting that these motions are clear we stop short of the unsolved problem of the expanding universe and of the effect of the theory of relativity upon our conceptions of time and space. Also we leave open the question of molecular and atomic motions where revolutions are just as important as those that Copernicus dealt with. The Earth, the Sun, the stars, and the galaxies seem to be well within our grasp, but we need another Copernicus to straighten out the very large and the very small worlds for us.

It is rather striking that the new picture of the Sun's position in the galaxy, and of the relation of our galaxy to the others, was developed largely in the interval between the two great wars. Even Copernicus had to take time out to be a soldier. We only wish that we could be more optimistic about the present state of the world leading us to a fuller understanding of the heavens. One hundred years hence there will be a quinquecentennial of Copernicus, and no matter how dark the present years and how crude our ideas become in retrospect, the name of Copernicus will continue to shine.

Washburn Observatory, Madison, Wisconsin.

Copernicus, the Founder of Modern Astronomy

By CURVIN H. GINGRICH

It is only with great difficulty that one, having completely accepted a basic principle of thought, is able to recover the point of view held by him before the principle was understood. It is still more difficult for us, living in this scientific age, to place ourselves in the attitude of mind of thoughtful persons before the current scientific principles were evolved.

In our moments of exaltation, we may feel that we today possess greater mental acumen than did our predecessors. However, in moments of normal mental states, we see plainly that the phenomenon of deeper discernment, clearer insight, and wider dispersion of knowledge in this age is fully accounted for by the fact that we are living in a later period. Upon reflection the honest mind is led to the conclusion, reached by Sir Isaac Newton, whose keenness of intellect, according to the verdict of history, has never been surpassed and seldom equalled, and cogently expressed by him in the well-known phrase, "If I have seen farther than most men, it is because I have stood on the shoulders of giants."

The development of the science of astronomy, which is the theme for this occasion, from the naive impressions arising as a consequence of casually noticing the regular and systematic changes in the sky to the highly technical researches now conducted by means of the most delicately constructed instruments is the result of the contributions made by these giants, each in his turn. A survey of the history of our civilization reveals the following named personalities as definitely towering above their contemporaries in the matter of astronomical interest and understanding. 1. Pythagoras (sixth century B.C.); 2. Hipparchus (*c.* 150 B.C.); 3. Ptolemy (*c.* 150 A.D.); 4. Copernicus (1473-1543); 5. Tycho Brahe (1546-1601); 6. Galileo (1564-1642); 7. Kepler (1571-1630); and 8. Sir Isaac Newton himself (1642-1727). It will be noticed that in some instances these followed each other in rather close succession while in other instances they followed only after long intervals of time. The elapsing of fourteen centuries between Ptolemy and Copernicus is notable. It is to this situation that we now direct our attention.

In the former of these two persons, Claudius Ptolemaeus, commonly known as Ptolemy, Greek astronomy may be said to have reached its climax. Little is known of the life of this person except that he lived in Alexandria during the second century A.D. It is extremely doubtful whether his name would occupy so prominent a place in the history of astronomy, were it not for the fact that he had great genius for organization. He systematized the thought of that age and the results of his

*An address given at State Teachers College, Maryville, Missouri, on May 7, 1943, in connection with the commemoration of the Copernican Quadricentennial.

labors came to be called "the greatest." This phrase translated into Greek and modified by a bit of Arabic influence leads to the common name of his epochal work, namely, "The Almagest."

Six or seven centuries before the preparation of "The Almagest" by Ptolemy, some of the questions with which it deals were considered. Pythagoras (approximately 500 years before Christ) and his followers had taken a step in the right direction in declaring that the Earth is a sphere, an idea quite contrary to the appearance of things which suggested that it was a disc of land possibly floating, but certainly completely surrounded by water. However, they still regarded the Earth as stationary at the center of the universe. One of the Pythagoreans, Philolaus by name, a century later, ascribed motion to the Earth. He, however, ascribed the same sort of motion to the Sun itself, and hence he cannot be credited with an insight into the actual celestial conditions which we now know to be the true ones.

In the fourth century B.C., Eudoxus, a pupil of Plato, attempted an explanation of the observed celestial motions. Starting, as was the custom, with the Earth as the center of motion, he devised an elaborate system of concentric spheres, each carrying its own celestial objects, yet each having a motion independent of that of the others, but all concentric. His plan required 27 spheres, which number soon thereafter, for the purpose of greater refinement, was augmented to 34, and later by Aristotle, about 350 B.C., to 56.

The spheres, according to Aristotle's viewpoint, were material in character and in some way impinged upon one another, thus mutually affecting their motions. The mechanical effects, however, were not clearly explained because the science of mechanics was not sufficiently developed at that time to cope with the complexity involved. He, along with other philosophers of his time, correctly considered the Earth and the heavenly bodies to be spherical. He thought this to be true also of the heavens themselves. He deduced arguments to establish the sphericity of the Earth and the Moon. As for the other bodies the belief that they were spheres was based largely on the feeling that, since the sphere was the "perfect" figure, nature would necessarily use that form. Aristotle could not accept the thought of motion of the Earth around the Sun, because, as he said, such motion would cause an apparent motion in the fixed stars which had not been observed. This was a telling argument, one which was not finally disposed of until the effect here required, known as parallax, was discovered by Bessel in 1838. The fallacy in his reasoning in regard to parallax, we now know, lay in his failure to appreciate the enormous distances to the fixed stars. So great was Aristotle's influence in some respects that his word was accepted as authoritative in all matters for many centuries to come.

Following Aristotle the names of Heraclides of Pontus and Aristarchus of Samos must be mentioned in a discussion of the development

of cosmological thought. The former quite correctly ascribed the diurnal motion of the stars to the rotation of the Earth on its axis. He also explained the appearance of Mercury and Venus now on one side of the Sun and now on the other as being due to revolution about the Sun. Later, possibly by someone whose name has been lost, Mars, Jupiter, and Saturn were put in the class of bodies revolving about the Sun, but strangely enough, the Sun was still supposed to revolve about the Earth.

Aristarchus of Samos went one step further and included the Earth with the other planets, all revolving around the Sun as a fixed center. He even surmised that the stars were so remote that apparent motion in them due to the Earth's motion in space would be so small as to be undetectable. These ideas, however, were so revolutionary, so much at variance with the current philosophy, so contrary to religious preconceptions that they failed to become recognized. They could not compete with the geocentric systems which were more acceptable, because they left the Earth in what was commonly believed to be its appropriate place, and which were constantly being brought into closer and closer agreement with observations.

The success of the geocentric system, which involved motion in circles whose centers moved along other circles, in so accurately representing the somewhat puzzling wanderings of the planets, is due to the skill of the "great geometer" of antiquity, Apollonius of Perga, who understood the mathematical properties of epicycles and deferents sufficiently well to adapt them to the needs of the situation.

One other astronomer before the time of Christ and possibly the greatest of that era remains to be mentioned, namely Hipparchus. Although he still failed to sense the true organization of the solar system, nevertheless, he made some valid discoveries concerning it. Usually proceeding from false premises one is led to false conclusions. Fortunately for Hipparchus, his work was not directly dependent upon a correct understanding of the fundamental relationships involving the Sun and the planets, and hence it was, in most respects, unaffected by the shift from an erroneous basis to the true one, as was done later.

He invented and developed the branch of mathematics which now is known as trigonometry; he constructed instruments of precision and made extensive observations with them; he saw the importance of observations extending over long periods of time and made use in his investigations of work done by earlier Greeks and Babylonians; he developed to a high degree the use of eccentrics and epicycles in explaining the motions of the Sun and the Moon. He determined the length of the year quite accurately; he found the Sun to be larger than the Earth, but failed to state accurately how much larger; he gave quite closely the diameter of the Earth and the distance from the Earth to the Moon; and he is generally credited with the discovery of the precession of the equinoxes.

The significance of the contributions of Hipparchus to astronomy is indicated by the following comment by Delambre in his "History of Ancient Astronomy":

"When we consider all that Hipparchus invented or perfected, and reflect upon the number of his works and the mass of calculations which they imply, we must regard him as one of the most astonishing men of antiquity, and as the greatest of all in the sciences which are not purely speculative, and which require a combination of geometrical knowledge with a knowledge of phenomena, to be observed only by diligent attention and refined instruments."

We advance now into the Christian era with a further consideration of the work of Ptolemy who lived in Alexandria about 150 A.D. Reference has already been made to the fact that the publication of "The Almagest" by him constituted his most important service. In fact it is in this work that we find a record of much that Hipparchus, and others, had done, which, but for this, might not have been preserved.

As was customary in works of this kind, notably in the case of Euclid's Elements, "The Almagest" was divided into books, thirteen in number. Briefly the several books contain material as follows:

The first two are concerned with the commonly observed astronomical facts, such as the celestial sphere overhead, the daily courses of the heavenly bodies, the length of the day, and the times of rising and setting of stars; also certain mathematical tables. In these books are stated Ptolemy's postulates, according to which the Earth is spherical, is the center of the heavens, is merely a point relative to the distances to the fixed stars, and is motionless.

The third book deals with the length of the year and the theory of the Sun and is essentially a recapitulation of the work of Hipparchus.

Book four treats of the length of the month and the theory of the Moon, and contains some results which were original with Ptolemy.

Book five contains a description of Ptolemy's chief astronomical instrument for making observations, namely, the astrolabe. It also relates to the study of the distances of the Sun and the Moon.

Book six is devoted to eclipses and again is largely a record of the work of Hipparchus.

Books seven and eight contain a catalogue of stars which bears a striking resemblance to the catalogue made by Hipparchus. The positions are different from those given by Hipparchus to the extent supposedly due to precession. The correction was erroneous, and hence the positions given ostensibly as the results of observation cannot be verified. The catalogue contains 1028 stars.

The last five books contain the gist of "The Almagest." It is here that the Ptolemaic theory of the planets is set forth. Ptolemy here followed the pattern of those who preceded him in that he, as well as they, was unable to avoid two fixed ideas, namely, that the Earth is the center of

the universe, and that the paths of the celestial bodies must be limited to circles. The fact that, although his basic principles were fundamentally wrong, he was able to represent the observations of the ancients and those of Hipparchus and himself so well indicates his skill and his genius as a mathematician. De Morgan classes him with Archimedes, Euclid, and Appolonius, the three great geometers of antiquity. The stars, and especially the planets, in their courses seemed to attest the soundness of the Ptolemaic theory. It had the weight of the argument of pragmatic philosophy back of it. The heavens seemed to be properly described by it, hence no need of any other theory was felt. There were no essential discrepancies, hence no questions were left unanswered.

The Almagest set astronomical thinking in a mold which remained unchanged for nearly fourteen centuries. The Middle Ages and the Dark Ages intervened before any important new ideas were injected into cosmology. It was not until the early part of the sixteenth century that a new and revolutionary voice was raised. The long period of relative inactivity from Ptolemy to Copernicus is the more impressive when one reflects upon the enormous changes which have taken place in astronomical theory and practice in the time since the death of Copernicus, the latter period being only approximately one-third as long as the former. Fortunately, although little progress was made during the intervening centuries, the scientific thought of the anciens was not lost. The Arabic scholar, Albategnius, Ibn Yunos, in Cairo, Arzachel in Spain, Nassir Eddin in Persia, Ulugh Begh in Russia, Regiomontanus in Vienna, Leonardo da Vinci in Italy, each had a part in carrying the torch of scientific learning through the Middle ages and of bringing it unaugmented, albeit also undiminished, to the threshold of the Renaissance.

From this point on our interest on this occasion centers in one person, Nicholas Copernicus. He was born in the town of Thorn (Torun) on the Vistula on February 19, 1473, and died in Frauenberg on May 24, 1543, four hundred years ago, hence the Copernican Quadricentennial.

The record shows him to have been an exceedingly versatile person. Quoting from Stephen P. Mizwa, "He was a churchman, a painter and a poet, a physician, an economist, a statesman, a soldier, and a scientist; a churchman by the wish of his guardian uncle and by vocation, an artist for relaxation, a physician by training and predilection, an economist by accident, a statesman and soldier by necessity, and a scientist—by the Grace of God and by sheer love of the truth for truth's sake. 'Yet he found time' says the English historian of astronomy, A. M. Clerke, 'to elaborate an entirely new system of astronomy, by the adoption of which man's outlook on the universe was fundamentally changed'."

It was the qualification mentioned last in this quotation, namely, that of being a scientist—more particularly an astronomer—which has perpetuated his name. With him the era in which the Ptolemaic System

was predominant was ended and the era of the Copernican System was begun. The essential difference between these two systems may be condensed into a single sentence. In fact one of his contemporaries, a churchman, in attempting to discredit his theory scoffingly characterized him as "that Sarmatian (Polish) astronomer who would move the Earth and stop the Sun."

Realizing the profound truth, thus unintentionally expressed, the Polish people have adopted it and made it a highly prized watchword of their nation. It occurs in permanent form in an inscription on a monument erected to Copernicus in the University Church of St. Ann in Krakow as follows:

> "The Sun he bade to stop and at his bidding the Earth began to spin.—Poland has nurtured him."

From the vantage point of the present, more than four centuries later, the implications so tersely stated in this inscription can readily be accepted by us. But the transition in thought from the old to the new was not and could not be accomplished suddenly and abruptly. The Ptolemaic system had in its favor, first, the fact that it was old and hence was entitled to the veneration accorded to age; second, the fact that it satisfied ecclesiastical dogma in that man, the acme of creation, had his abode, the Earth, at the center of the universe; third, the fact that it was in keeping with the naive conclusions reached by the senses; for anyone who wished might observe the Sun by day, and the stars night, rise in the east, pass overhead, and set in the west, while he continually felt beneath his feet the solid, substantial, and, to all appearances, the stationary Earth. Nevertheless, Copernicus, having learned, as a result of six years of study in Italy, that certain of the ancients had conceived of a moving Earth, was greatly impressed with the possibility of such a situation. After much thought he became convinced of its validity. In his own words we have his conception of the Universe, as follows:

"First and above all lies the sphere of the fixed stars, containing itself and all things, for that very reason immovable; in truth the frame of the Universe, to which the motion and position of all other stars are referred. Though some men think it to move in some way, we assign another reason why it appears to do so in our theory of the movement of the Earth. Of the moving bodies first comes Saturn, who completes his circuit in 30 years. After him, Jupiter, moving in a twelve year revolution. Then, Mars, who revolves biennially. Fourth in order an annual cycle takes place in which we have said is contained the Earth, with the lunar orbit as an epicycle. In the fifth place Venus is carried round in nine months. Then Mercury holds the sixth place, circulating in the space of eighty days. In the middle of all dwells the Sun. Who, indeed, in this most beautiful temple would place the torch in any other or better place than one whence it can illuminate the whole at the same time? We find, therefore, under this orderly arrangement a wonderful

symmetry in the Universe, and a definite relation of harmony in the motion and magnitude of the orbs, of a kind it is not possible to obtain in any other way."

This finished, and essentially correct, statement shows the final conclusions Copernicus arrived at. The fundamental and radical difference between this point of view and that of the ancients is unmistakable. It is interesting to note the caution he used in expressing his conviction. Consider for example the following guarded and conciliatory statement, tentatively put forth by him:

"If, therefore, one should maintain that the Earth is not in the center of the universe, but that the discrepancy between the two is not great enough to be measurable on the sphere of the fixed stars, but, on the other hand, noticeable and recognizable in the orbits of the Sun and the planets; and if further he were of the opinion that the motions of the latter for this reason appear irregular, just as if they were oriented with respect to another center than that of the Earth—such a person might, perhaps, have assigned the true reason for the apparently irregular motions."

To defend and substantiate the thesis that the Earth, instead of being motionless at the center of the Universe, possessed a rotation about its axis and also a revolution about the Sun, as the center of the universe, it was necessary for Copernicus to meet and dispose of the arguments against the thesis which hitherto had been powerful enough to prevent its acceptance.

One argument, which Copernicus ascribes to Ptolemy himself, which was intended to show the impossibility of the axial rotation of the Earth, stated that as a result of such rotation an object tossed into the air would return to a spot some distance west of its starting place, the point from which it started having moved eastward in the meantime; also, the clouds would be always moving westward with tremendous velocities because of the great currents of air moving in that direction; and moreover the rotational speed would be so great that the Earth long since would have become separated into parts and dissipated throughout space, and all living things have been annihilated. This obviously has reference to centrifugal force, although that term was not used or fully understood.

The mechanical principles involved not being clearly recognized by him, Copernicus could not refute the argument on that basis. He first used the philosophical reasoning that axial rotation being natural would for that reason not be self-destructive. For nature tends to preserve rather than to destroy itself. Then with more telling practical effect he called attention to the fact that the alternative to a rotating Earth was a rotating universe, which being vastly greater would require vastly greater velocity and hence be much more subject to disintegration. Finally, although both hypotheses represented the phenomena equally

well, the rotating Earth being the simpler, was therefore the more plausible. Again in the words of Copernicus, "Moreover, the condition of rest is considered as nobler and more divine than that of change and inconstancy, so the latter would be more suited to the Earth than to the universe." And thus that objection was met.

The most powerful argument against the revolution about the Sun, as was stated earlier, was the claim that then the stars should show apparent displacement in the opposite direction. Copernicus admitted this but asserted that, due to the great distances involved, the displacement would be so small as to be undiscoverable. This explanation has been completely established by modern observations. He asserted that many features relating to the planets would be so greatly simplified by such revolution as to be demanded by the harmony of the universe. All of this becomes convincing "if," as he says, "we only (so to speak) look at the matter with both eyes."

With so able an advocate and because of its inherent strength the Copernican system, appearing as it did when a revival of interest in learning was taking place, and when new worlds were being discovered, gradually won acceptance and has continued to represent the basic cosmological thought to the present time.

If one were to judge solely from the scattered and rather sketchy quotations here used, he might thing that the work of Copernicus was meager and speculative in character, and that he merely was fortunate in hitting upon correct ideas. Such a conclusion would be erroneous. There is, fortunately, a considerable amount of his original writing available for the student. It is included chiefly in four treatises.

First, the *Commentariolus* or brief commentary. This was not published in his life-time, only hand written copies having been made and circulated. They were then completely lost sight of and came to light again only toward the end of the nineteenth century, one in Vienna, and one in Stockholm. It is believed that a third exists in Leningrad. It bears evidence of having been written before the ideas concerning the celestial motions had taken final form.

Second, the *Letter against Werner*. This was prompted by a collection of papers on mathematics and astronomy by John Werner, a contemporary. A copy was sent to Copernicus by one who had been a fellow student at the University of Krakow, requesting him to pass judgment on it. In 1524 Copernicus sent his reply in a letter, hence the name. The letter really was what we would call a thoroughgoing book review, and afforded an opportunity for Copernicus to express his views which in general were opposed to those of Werner. It was sufficiently extensive to constitute and to be regarded as one of the minor astronomical works of Copernicus.

Third, the *Narratio Prima*, or *First Account*. This, strictly speaking, is not a writing by Copernicus, but is an accurate statement of his work.

It was written by George Joachim Rheticus who was attracted to Copernicus by the fame which had already become associated with his name. Up to this time Copernicus had refused to concur in the earnest solicitations and urging on the part of his friends that he submit his work for publication. It seems that, in spite of his courage in thinking along new and almost forbidden lines, he showed great timidity in bringing his discoveries to light. This attitude of mind is disclosed by him in a sentence in the introduction to his great work when it finally did appear. He says, "When, therefore, I had pondered these matters, the scorn, which was to be feared on account of the novelty and the absurdity of the opinion, impelled me for that reason to set aside entirely the book already drawn up." Rheticus, himself a thorough student, entirely competent to evaluate the significance and importance of the work of Copernicus, added his influence in the direction of early publication. Failing in this, he wrote a rather complete account ostensibly in the form of a letter to his friend Schöner. This account was published in 1540 and was accorded a most favorable reception. It is quite probable that this circumstance was the argument which finally induced Copernicus to have the material, upon which he had spent many years of thought and labor, prepared for publication. This epoch-making treatise then was finally to appear under the title *De Revolutionibus Orbium Caelestium. Concerning the Revolutions of the Celestial Spheres.* It was divided into books as was customary; in this case six. We cannot here go into the details of its contents. Suffice it to say that it bears the mark of a great mind at work, one which was capable of using successfully mathematics and especially geometry, which constitutes the "staff of the astronomer."

When the manuscript was given to the printer, Copernicus had already almost attained the allotted three score years and ten. He, therefore, was unable himself to supervise the proof-reading and printing. This responsibility Copernicus was willing to entrust to his admirer, friend, and pupil, Rheticus. Unfortunately, or perhaps, fortunately, Rheticus, being obliged to leave Nuremberg, in turn transferred the responsibility to Andreas Osiander, a local Lutheran theologian and mathematician of some note. We said, unfortunately, because this person on his own authority inserted a preface expressing a point of view which he had previously urged upon Copernicus but which Copernicus had not accepted. His preface intimated that this work was put forth merely as a working hypothesis and not necessarily as an exposition of true facts. It was inserted too late to be discovered by Copernicus and, being unsigned, it was for a time regarded as a statement by Copernicus. Its real authorship early became known to a few, but not until some years later did the facts become generally known, and then through the writings of Kepler.

We said, perhaps after all it was fortunate that Osiander was given

such responsibility, because his motive in inserting his preface was undoubtedly well intentioned. He, as well as Copernicus, foresaw the likelihood of hostile criticism and, by this preface, thought to forestall or at least to minimize it. The tenor of the preface was at variance with the claims made in the body of the volume but this discrepancy was not immediately noticed. The preface by Osiander, then, served to ease the shock involved in the break with the past which was necessitated by an acceptance of the conclusions reached in *De Revolutionibus*. That such tempering was desirable is indicated by the facts that, even so, a century and a half elapsed before the Copernican system was accepted by European scholars, and another generation passed before it was openly taught at Oxford, the Sorbonne, and in America. It was as late as 1721 before the American divine and author, Cotton Mather, was willing to concede that the "Copernican hypothesis is now generally preferred" and that "there is no objection against the motion of the Earth." Osiander's preface, therefore, need not be regarded as entirely gratuitous.

Before the printing was done, Copernicus was stricken with a mortal illness. His great concern was that the printing of the book might be too long delayed, and that consequently he might not live to see it. It is quite well established that, as a matter of fact, the first copy was hastily brought from the printer in Nuremberg to Copernicus in Frauenberg, the messenger bearing it arriving only a few hours before Copernicus' death. Copernicus was no longer able to read its contents but he touched the volume and sensed that it was, indeed, the most important part of his life work, and then died with a peaceful mind and spirit.

Alfred Noyes, in "Watchers of the Sky" has dramatized this incident in these lines—

> "A shadow moved toward him from the door.
> Copernicus, with a cry, upraised his head.
> 'The book, I cannot see it, let me feel the lettering on the cover. It is here!
> Put out the lamp, now. Draw those curtains back,
> And let me die with starlight on my face.
> An angel's hand in mine. . . Yes, I can say
> My *nunc dimittis* now . . . light, and more light,
> In that pure realm whose darkness is our peace'."

Four hundred years later we, along with many others, in this land far removed are commemorating the events of that historic occasion. Today we look upon the ancient University of Krakow, the Alma Mater of the great Copernicus, closed for the first time in nearly six centuries, its illustrious faculty dispersed if not annihilated by the invader. We look upon the cities of ancient Poland laid waste by the despoiler. We look upon a nation humiliated under the heel of a merciless conqueror; a nation which for a century or more has suffered the ignominies which the greater and more powerful nations have been wont to inflict upon the smaller and weaker ones; a nation which in a brief interval of peace and security—1918 to 1939—began to rebuild its historic greatness, only to be hurled again into the deepest despair by the tragedy of the

Second World War; but, withal, we look upon a nation which throughout its vicissitudes has held resolutely to the dignity of its nationhood, and unconquerably to a belief in a glorious destiny.

Four hundred and seventy years ago Poland gave birth to a great spirit, Nicholas Copernicus. Could it be that out of ceremonies, such as these, commemorative of the contributions he made to science, to civilization, to humanity, there might arise a new spirit which, in the fullness of time, in its turn may give birth to a new and greater Poland.

God grant that it may be so!

Changing Ideas of the Universe

By MAUD WORCESTER MAKEMSON

If you watch the sky for a few hours during any clear evening, you will see that all the heavenly bodies march in endless and orderly procession from east to west. We know today that this motion is only an apparent effect, caused by the rotation of the Earth on its axis; but until the middle of the 17th century, the Earth's motion was far from being a universally acknowledged fact.

If, moreover, you watch the pageant of the stars over a period of several months, you will discover that the same constellations do not rise at the same time each night, but a gradual change takes place. Thus certain configurations are conspicuous on winter nights, and entirely different constellations are associated with the skies of spring, summer, or autumn. We know now that this change in the aspect of the heavens during the course of the year is also an apparent effect, caused by the Earth's annual revolution in its orbit about the Sun; but such knowledge has only been won after a long and bitter struggle against the accepted opinions of the ages.

If, finally, you chart the stars on various nights, you will discover that there are five bright objects, apart from the Moon, which move about erratically on the face of the sky. These the ancients called planets, "wanderers," and they are still so known today. The irregularities in the trails which they blaze among the stars, as well as in their size and brightness, are due to the fact that we view them from a rapidly moving Earth.

For many astronomical problems, particularly those of navigation and surveying, it is much more convenient to proceed as though the apparent motions were the actual ones; but when an attempt is made accurately to predict future positions of Sun, Moon, and planets on the basis of their apparent movements alone, the problem becomes extremely complex if not insoluble. Not until the 17th century did men perceive the possibility that physical forces, rather than angelic beings, kept the celestial bodies moving in their orbits.

More than a century after the Copernican theory was given to the world and twenty years before the publication of Newton's *Principia,* the poet Milton expressed the popular opinion of the times in *Paradise Lost,* that God had intentionally concealed the secrets of the universe from mortals and was amused by their attempts to fathom His laws. When the angel Raphael explained the creation of the world to Adam, the latter naturally asked the great controversial question of the 17th century, whether the Earth moved, or the Sun. And the angel replied:

> To ask or search, I blame thee not; for Heaven
> Is as the book of God before thee set,
> Wherein to read his wondrous works, and learn
> His seasons, hours, or days, or months, or years.
> This to attain, whether Heaven move or Earth
> Imports not, if then thou reckon right. The rest
> From Man or Angel the Great Architect
> Did wisely to conceal, and not divulge
> His secrets, to be scanned by them who ought
> Rather admire.

To understand the changing ideas about the universe which finally culminated in the long-delayed triumph of Copernican theory, we must review the works of the Greek astronomers which inspired Renaissance scholars to strive for an understanding of the heavens. Beginning with Pythagoras about the middle of the sixth century, B. C., and ending with Ptolemy 700 years later, Greek astronomy gradually developed from abstract, philosophical reasoning as to what was the most appropriate behavior for a celestial body into a mathematical science founded on observation, by which future positions of Sun, Moon, and planets could be predicted with a surprising measure of exactness.

The Pythagoreans taught that the Earth is a sphere; that the Moon and planets are spheres shining by reflected sunlight, and inhabited with beings of the same nature as those on the Earth. The animals on the Moon were said to be fifteen times as strong as terrestrial animals, probably because a day on the Moon equals fifteen earth-days.

Number was the essence, the very substance, of the universe. The Sun, Moon, and planets totaled the sacred number seven. These planetary bodies moved about the Earth in circles, the motive power being harmony. They were spaced according to the intervals between musical notes, and the eighth or stellar sphere completed the octave. As they circled ceaselessly, they gave forth celestial music. You could not hear these heavenly harmonies because you were too much accustomed to them, like people who live near a waterfall, and do not hear the roar of the water.

Toward the end of the fifth century, the Pythagorean, Philolaus, improved this simple cosmogony. It occurred to him that if all the heavenly bodies move in endless circles, their periods of revolution decreasing with nearness to the earth, it was reasonable to believe that the Earth also possessed a circular motion about the center of the uni-

verse. He therefore advanced the theory that the Earth revolved in a small circle every 24 hours, keeping its uninhabited hemisphere always toward the center, and its inhabited half turned outward toward the stars. Just so does the Moon circle about the Earth, keeping the same face toward us.

The center of the universe could not be empty, however, and Philolaus conceived it to be occupied by a great central fire, which he called "the hearth of the universe," and the "watch-tower of Zeus." No one had ever seen the central fire, of course, but that was simply because it was visible only from the unihabitable half of the Earth, which was all ocean or desert. With the addition of the Earth and the central fire to the ranks of the heavenly bodies, it was necessary to look for one more planet, in order to bring the total up to the sacred number ten. This he accomplished by postulating a "counter-earth," which revolved in the Earth's orbit but always remained on the other side of the central fire. (Fig. 1.)

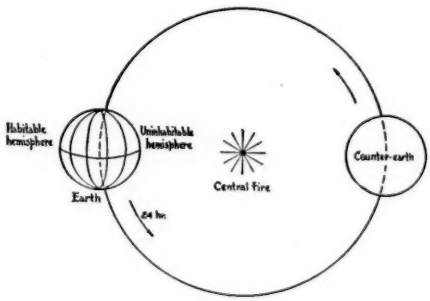


FIGURE 1

The Earth's Daily Motion, according to Philolaus, 5th Century B.C.

The theory of the Earth's motion had the tremendous advantage that it explained the diurnal rotation of the heavens which is shared by Sun, Moon, planets, and stars equally, by the simple revolution of the Earth in a small circle every 24 hours.

Toward the end of the fourth century, B.C., the theory was further improved by the last of the great Pythagorean astronomers, Heracleides of Pontus. With a single magnificent gesture, he transferred the central fire to the center of the Earth, eliminated the counter-earth, and set the Earth to rotating daily on its axis in the center of the universe. Thus he arrived at the true explanation of the diurnal rotation of the heavens, a remarkable achievement. No longer forced to conceive of the stars as embedded in a crystal sphere which spun daily on an axis through the Earth, the Pythagoreans taught that each star was a world suspended in infinite space,—an advanced theory, indeed.

Fifteen centuries later, when the medieval European church adopted

Greek astronomy and philosophy, the fire at the center of the Earth was to come in very handy. Since Hell and Purgatory must necessarily be situated as far as possible from the all-encircling heavens, what better place could be found for them than in the middle of the Earth? Thus the Pythagorean Hearth of the Universe became the Christian Hell, the need for which had not been foreseen by Aristotle when he designed his perfect and eternal cosmos.

The "music of the spheres" also caught the imagination of the early church fathers, although it had been rejected by Aristotle as merely a "pretty idea." Milton reflected the universal belief when he wrote, in the Hymn on the Nativity:

> Ring out, ye crystal spheres,
> And with your nine-fold harmony
> Make up full concert to the angelic symphony.

And Shakespeare, in the Merchant of Venice:

> There's not the smallest orb which thou beholdest
> But in his motion like an angel sings.

The advances of the Pythagorean astronomers were rejected by the rival school which developed in Athens during the fourth century, B.C., and which was to dominate the civilized world for 2000 years. Plato reasoned that in the beginning there was chaos. Then the Creator, wishing to pattern a universe which would express his own goodness, made the four elements, Earth, water, air, and fire. The Earth, being made of the heaviest material, rests, motionless, in the exact center of the universe, since to this point all heavy bodies tend to fall. Water, being a heavy element, but lighter than Earth, rests upon the Earth. The light elements, air and fire, tend to rise. Thus there is a sphere of fire, resting on the air under the sphere of the Moon. Comets and meteors were generated in the sphere of fire by dry vapors rising from the Earth.

Sun, Moon, planets, and stars are embedded in vast solid orbs which revolved ceaselessly about axes passing through the center of the earth. The spinning orbs were the abodes of various orders of celestial beings, their rank increasing with their distance from the inert Earth. This aspect of Plato's teaching appealed strongly to the Church fathers, who peopled the celestial spheres with the nine hierarchies of angels. Plato's creation of the world from chaos also agreed beautifully with the Biblical account of creation.

Plato is said to have inspired Eudoxus to undertake the formidable task of devising a mechanism which would explain the complicated observed motions of the heavenly bodies. Eudoxus studied astronomy in Egypt with a priest of Heliopolis, and returned to teach his ingenious theories in Athens, in the middle of the fourth century, B.C. He accepted Plato's dictum that the heavy inert Earth occupies the center of the cosmos, while all the celestial bodies are carried around it. To each

planet he assigned four contiguous spheres, centered at the Earth, each of which was capable of a single rotation. The observed path of the planet on the sky was the resultant of these four rotations, since each sphere transmitted its own motion to the quadruple system. One such orb was required, for example, to impart the diurnal motion. Another turned in a period equal to the planet's synodic revolution. The other two accounted for the retrograde movements. The Sun required only two such orbs, one turning in 24 hours, the other in a year. (Fig. 2.) Since the stars possess only a diurnal movement, one sphere sufficed for them.

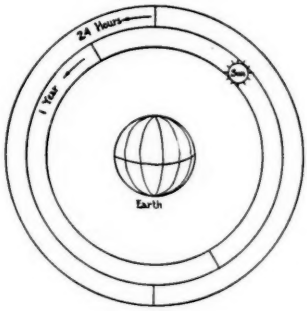


FIGURE 2

The two Solar Spheres, according to Eudoxus, 355 B.C.

Around 330 B.C., Eudoxus' pupil, Calippus, improved his teacher's system by the addition of one more sphere each to Mercury, Venus, and Mars and two apiece to the Sun and the Moon, bringing the total number from 27 to 34. The Athenian school had access to the recorded observations of Babylon and Egypt of many centuries, and their ingenious attempts to construct a mechanism which should satisfy observations or "save the phenomena," deserve the highest praise. Nevertheless, even the improved system of Calippus did not account for the observed variation in the diameters of the Sun and Moon and in the brightness of the planets, due, of course, to their changing distances from the Earth; for all the bodies moved in circles and therefore maintained a uniform distance from the Earth.

Aristotle gave the weight of his great authority to the mechanism as improved by Calippus, except for one innovation. It seemed to him that the vast whirling sphere of the stars must assuredly communicate its diurnal motion to all the other bodies, since everything shared this revolution equally. If a force was thus transmitted from the outermost sphere inward to all the other orbs, each of the planetary spheres must likewise communicate their rotations to all the others. So, in order to account for the observed results, he interposed sets of "unrolling"

spheres between the systems of the planets, which had the function of neutralizing all the motions except the diurnal rotation. Since a sphere was a "simple body," and a simple body could possess only one axial rotation, there had to be an unrolling sphere for each planetary sphere except the one which imparted the diurnal motion, and the total number grew to 55. Thus Aristotle pictured space as entirely filled with substantial spheres.

He taught that there were three "natural" motions: gravity, or motion downward, which was possessed by all heavy bodies; levity, or motion upward, a quality of light bodies such as air and fire; and motion in a circle about an axis, possessed by spheres. He rejected Plato's picturesque "world-soul" and his theory of the creation, teaching that the universe has always existed and will always continue to exist, perfect, incorruptible, unchanging, and eternal. He rejected the Pythagorean music of the spheres and the concept that harmony was the motive power of the cosmos. The spheres rotate, he said, simply because it is their nature to rotate. He did, however, postulate a "First Mover, himself unmoved," who was later identified with the Christian God.

To the four elements of Plato, Earth, water, air, and fire, Aristotle added a fifth, the ether, as the substance of which the celestial bodies and their spheres consisted. Dante, in the *Paradiso,* describes the ether as white, dazzling, and translucent, polished like a pearl, hard as adamant, yet soft as a cloud, offering no resistance as he passed through it like a beam of light through water.

Four and a half centuries after Aristotle placed the seal of his approval on the system of Eudoxus and Calippus, Ptolemy of the Alexandrian school made the final contribution to Greek astronomy. In the meantime, however, Aristarchus of Samos, in 230 B.C., had taught the modern theory that the Earth not only rotates daily on an axis, but revolves annually about the Sun. Since he could not bring forward observational proofs of his advanced theory, he had little influence on the minds of his contemporaries. Hipparchus, around 150 B.C., charted 1080 stars with such accuracy that he discovered precession of the equinoxes.

Ptolemy, around 150 A.D., devised a purely mathematical method for representing the motions of the heavenly bodies and predicting their positions, as closely as they could be observed without instruments of precision. Each planet revolved in a small circle, the epicycle, whose center moved, in turn, about a large circle, the deferent, in such a way that its angular velocity about a point known as the equant, remained constant. The motionless earth occupied the center of the universe, but not the center of the planetary deferents. Motion about the equant accounted for the change in the speed of the planet in various parts of its orbit. Motion on the epicycle accounted for the variability in diameter and brightness, with varying distance from the Earth. (Fig. 3.)

Ptolemy did not claim to have explained *why* the heavenly bodies moved in this way, and he obviously looked upon his circles as mathematical abstractions, not as solid spheres. It remained for the Arabs to reconcile his system with the ethereal orbs of Aristotle and they accomplished this feat by considering the epicycle and deferent as enclosed between two solid spheres. They also added a ninth sphere, the *primum mobile,* or first mover, beyond the crystal sphere of the stars, which had the function of maintaining the stellar sphere in its rapid diurnal rotation.

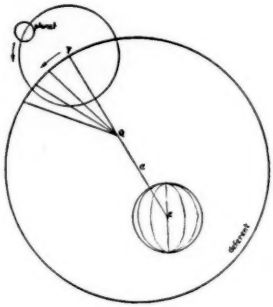


FIGURE 3

Ptolemaic System for one Planet (150 A.D.). E = Earth, Center of Universe; C = Center of Deferent; Q = Equant; F = Center of Epicycle.

When his teachings were first introduced into France about 1200 A.D., Aristotle was branded as an infidel and his works banned by the Church. Nevertheless, within 50 years they were on the required curriculum of the University of Paris, and it was infidelity not to believe in them. This result was due to the writings of the Dominicans, Albertus Magnus and his pupil, Thomas Aquinas, who succeeded in making an acceptable compromise between Greek philosophy, on the one hand, and Christian theology and mysticism, on the other.

No longer was the spherical Earth denounced as an "old heathen doctrine." Together with the crystalline spheres of Aristotle, it became an integral tenet of Christian faith. The spheres of the Sun, Moon, five planets, and the star-sphere, together with the ninth orb added by the Arabs, became the dwelling-places of the nine hierarchies of angels; and a tenth sphere called the empyrean was introduced beyond the ninth, as the abode of God and the more blessed spirits. Plato's creation from chaos was substituted for Aristotle's doctrine of eternal existence of the universe. The Pythagorean fire in the middle of the Earth was identified with Hell, and the music of the spheres continued to resound.

The Greek division of the Earth into habitable and uninhabitable hemispheres was accepted. The prophet Ezekiel had declared Jerusalem to be set down in the middle of the Earth. Jerusalem was, therefore, said to be in the center of the habitable hemisphere, since it was 90° from the Pillars of Hercules (Gibraltar) and 90° from the mouths of the Ganges. The Garden of Eden was located on the eastern edge of this hemisphere.

Unfortunately, Aristotle's cosmology had no practical applicability. When it came to the question of calculating the annual almanacs which were in such urgent demand for making astrological predictions, recourse was necessarily had to the Ptolemaic system. Astronomical tables based on the Ptolemaic theory were computed by King Alfonso of Castile and his Arab and Jewish astronomers in 1252. These were eagerly accepted throughout Europe and served astrology for 300 years, when they were superseded by the more exact tables derived by Reinhold from the Copernican system. By that time (1551) the Alfonsine tables were fully a month in error.

It must be confessed that the enthusiasm with which Greek astronomy was received in Europe was due, not so much to scientific curiosity, which was, indeed, considered impious by many, but to the universal preoccupation with astrology. This black art, called "judicial astronomy" after Ptolemy, was not frowned on by the Church, and the famous astrologers with whom Dante conversed in the Inferno were undergoing punishment, not for deceiving credulous clients, but for the crime of impiety, because they sought to penetrate too deeply into the future.

Every doctor of medicine was required to know "judicial astronomy" and to be adept in making astronomical observations, calculations, and prognostications; for, as the Arab saying went, "What good is a doctor who knows no astronomy? He is like an eye which cannot see!" This belief persisted into the 17th century, and astronomy was taught by the medical faculty at Oxford University until 1619, when the first chair of astronomy was established.

Thomas Aquinas popularized the Aristotelian-Ptolemaic cosmology, but Dante immortalized it, and the *Paradiso* presents an authentic and informative picture of popular medieval astronomical concepts. Conducted swiftly upward from the Earth by his beloved Beatrice, the poet found himself in the sphere which carries the Moon. There he questioned his guide about the dark markings on the lunar planet, which were the subject of much controversy on Earth. Beatrice obligingly explained that the heavenly bodies differ not only in brightness, but in the quality of their light, smilingly rejecting the theory that the Moon is merely a mirror which reflects the irregularities of the Earth's surface, or contains transparent veins, like alabaster.

They visited in turn the heavens of Mercury and Venus, planet of lovers, the Sun, Mars, abode of warriors, temperate Jupiter, and cold

Saturn. Passing through the sphere of the stars, they reached the *primum mobile* of the Arabs and were carried along by it, in its rapid revolutions about the motionless Earth. Dante's angelic spirits symbolize the celestial spheres. They express joy by radiating a dazzling light. They form circles within circles, or "wheels within wheels," and dance round and round emitting light, and singing with incredible sweetness,—the Pythagorean music of the spheres. An individual expresses delight by whirling very rapidly about, while remaining on the same spot, like a sphere rotating about its axis.

Such was the world into which Copernicus, the man of whom Martin Luther declared, "The fool will overturn the whole science of astronomy," launched his new-old theory of the cosmos in 1543. Luther's prophecy required more than a century for its fulfillment, for the world was not ready to deny the evidence of its senses and accept a mobile Earth, until the way had been prepared for a revolution of thought by the painstaking observations of Tycho Brahe, the astounding discoveries of Galileo, the mystical mathematics of Kepler, and the refutation of Aristotelian philosophy by Descartes.

Copernicus taught that the Earth rotates on its axis and moves in an annual orbit about the Sun, and he proved mathematically that by these two simple assumptions all the recognized phenomena of the heavens could be completely represented. Unable to free his mind from the Greek metaphysical concept that only the circle was appropriate for the path of a celestial body, he taught that the planets, including the Earth, revolved in circles about the Sun, which occupied the center of the universe, but was not in the exact center of the planetary orbits. Thus in a sense he foreshadowed Kepler's discovery, early in the 17th century, that the orbits of the planets are ellipses, with the Sun situated at one focus. On the hypothesis of circular movement, Copernicus was forced to retain some of the epicycles of Ptolemy in order to explain the observed irregularities in the behavior of the Moon and planets.

Although his system removed the necessity for believing that the stars were fixed on the surface of a sphere which whirled about the Earth every 24 hours, Copernicus and most of his successors for a hundred years still believed in the existence of a substantial stellar sphere. Apart from the emotional arguments based on commonsense and the Bible, the greatest obstacle in the evolution of the heliocentric theory was the fact that no annual oscillation of the stars could be observed. Copernicus answered this sound Aristotelian objection by declaring that the stars are at such enormous distances that the Earth's orbit shrinks to a point in space. The truth of his assertion was not established until 1838, when the infinitesimal annual displacement of stars was actually detected.

That the Copernican theory was so slow in accomplishing the revolution prophesied by Luther was due on the one hand to the dogmatic

belief in the metaphysical cosmology of Aristotle, and on the other hand to the well-established custom of regarding the mathematical system of Ptolemy as merely a convenient hypothesis for calculations. Thus the heliocentric theory slipped easily into the same category as the Ptolemaic system which it immediately replaced. As Milton remarked in 1667, it makes no difference what hypothesis you employ, so long as your calculations give the desired results.

The Copernican system did not offer a substitute for the metaphysics of Aristotle, and it remained for Newton to explain the "why" of the observed planetary motions by his discovery of the law of universal gravitation, which marked the true coming of age of astronomy.

VASSAR COLLEGE, POUGHKEEPSIE, N. Y.

Fels Planetarium Celebration of the Copernican Quadricentennial

By ROY K. MARSHALL

The Planetarium demonstration for the period April 26 through May 31 bore the title "Music of the Spheres," and was devoted to a colorful and dramatic recital of the life and work of Copernicus, and the later development of his ideas to final acceptance. A special musical arrangement was used as an Overture to the demonstration. It contained the traditional "music" as set down by Kepler in his *Harmonices Mundi* in 1619, and other elements (The "Broken Note" of the Trumpeter of Krakow, and "Gaude Mater Polonia") associated with Copernicus.

FIGURE 1

The "Music of the Spheres" as set down by Johann Kepler in his *Harmonices Mundi* (Lincii, 1619.)

A transcribed Prologue set the theme of the demonstration with, first, the lines summarizing the work of Copernicus.

> "The Sun he bade to stop, and at his bidding
> the Earth began to spin;
> Poland has nurtured him."

Then followed a poem of sympathy for Poland, in her hour of travail, and of admiration for her culture and lasting greatness. Then tableaux of ancient temple-astronomy and the interior of a modern observatory

were displayed by lighting effects peculiar to the Fels Planetarium equipment.

The lecturer's story followed, relieved by a demonstration of the projection orrery, designed and constructed at the Fels Planetarium. This shows the Sun and the nine planets as moving points of light at the zenith of the planetarium dome, properly timed and properly scaled. Tableaux of Ptolemy, with an Earth-centered transparency, and of Copernicus, with a Sun-centered transparency, were displayed at the moment when the transition from the ancient to the modern ideas was made.

On April 28, a press preview was given, attended by such notables as Dr. Sylvester Gruszka, Polish Consul for New York and Philadelphia, and Dr. Stephen P. Mizwa, Executive Secretary of the Kosciuszko Foundation of New York.

On May 24, demonstrations were given at 7:00, 8:00, and 9:00 P.M., for large audiences whose admission fees were turned over to Polish relief. The demonstrations were given in the Polish language, by Dr. Thaddeus Gorecki of the Central High School.

A feature of considerable interest during the celebration has been a book exhibit containing most of the links in the story of the development of the Copernican theory.

The Copernicana Exhibit at the Fels Planetarium

It was just ten years ago that the great burning of the books took place in Germany. Probably no books of irreplaceable nature were destroyed, for even a Nazi is shrewd enough not to let propaganda stunts inflict injuries upon his pocketbook. The book-burners of earlier days were sometimes not so careful, and many valuable volumes were destroyed in the name of religion and philosophy.

Fortunately for science, a few score volumes of almost any important work survived the fury of short-sighted conservatives, and this year most men who are interested in the physical sciences are turning their thoughts toward one particular volume which left the press in Nürnberg four centuries ago.

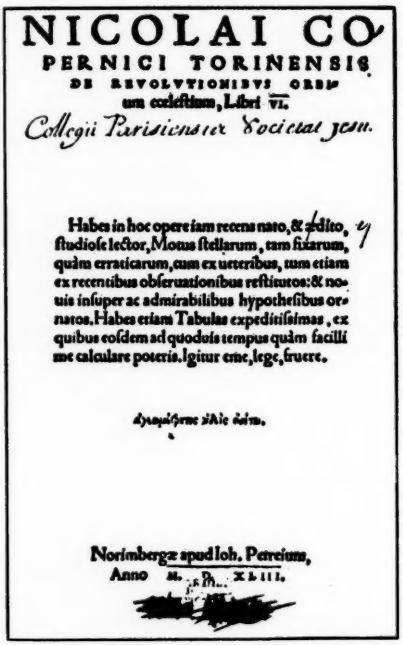
This year marks the quadricentennial of the death of Nicolas Copernicus, the Polish churchman-astronomer, and of the publication of his great work, *De Revolutionibus Orbium Coelestium* (Concerning the Revolutions of the Celestial Spheres).

From the beginning of time until the days of Copernicus, no one had seriously challenged the geocentric theory of the universe. It is true that some of the Greek philosophers had speculated on the problem, and had suggested that many of the appearances in the sky could be accounted for by a rotating Earth which revolved annually around the Sun, but such purely philosophical abstractions never travelled very far, and not once touched the minds of the non-scholarly "ordinary man."

In his book, Copernicus attempted to establish the facts that the Sun,

and not the Earth, is the center of the planetary system, and that the Earth is but one of the planets, revolving around the Sun once each year and rotating on its axis once each 24 hours.

Not for more than a century and a half was his work accepted generally and the labors and discoveries of many later men of genius were necessary before the heliocentric theory was brought to completion and acceptance.


NICOLAI CO
PERNICI TORINENSIS
DE REVOLVTIONIBVS ORBI
um coelestium, Libri VI.
Collegii Parisiensis Societat Jesu.

Habes in hoc opere iam recens nato, & edito, & studiose lector, Motus stellarum, tam fixarum, quàm erraticarum, cum ex ueteribus, tum etiam ex recentibus obseruationibus restitutos: & nouis insuper ac admirabilibus hypothesibus ornatos. Habes etiam Tabulas expeditissimas, ex quibus eosdem ad quoduis tempus quàm facillime calculare poteris. Igitur eme, lege, fruere.

Norimbergæ apud Ioh. Petreium,
Anno M. D. XLIII.

FIGURE 2
Title Page of Fels Planetarium
Copy of First Edition.

At the Fels Planetarium in The Franklin Institute, an extraordinary exhibition of books pertaining to the acceptance of the Copernican theory has been arranged as a part of the nation-wide celebration of the Copernican quadricentennial. The books in the collection are a part of the bequest of the late Dr. Gustavus Wynne Cook of Wynnewood, whose fine astronomical observatory is now a part of the equipment of the University of Pennsylvania.

The most important books in the exhibit are, quite naturally, copies of the work of Copernicus. The Fels Planetarium is fortunate in possessing copies of both the first (Nürnberg, 1543) and the second (Basel,

1566) editions of *De Revolutionibus*. Both are in excellent condition, in contemporary bindings.

Scarcely less important, however, are the exceedingly rare works of Johann Kepler, Galileo Galilei, Tycho Brahe, and Isaac Newton. Tycho was primarily an observer, and because his instruments were so far superior to those anyone else had ever made, he was forced to abandon a fleeting belief in the Copernican theory. For, said Tycho, if the Earth revolves around the Sun, we should be able to see the stars apparently shift in relative positions, from one time of year to a time six months later. With the great telescopes of today we do detect and measure these shifts, but Tycho could not discover them, so he said the Earth must be fixed. The alternative, that the stars were so far away that the shifts were too small for him to detect, was preposterous, in his mind, for that would imply that the stars were so far away that there would be a great stretch of empty space between the outermost known planet, Saturn, and the nearest stars, and that, said Tycho, would be wasteful! We might wonder what Tycho would have thought if he had been told that the nearest star is 30,000 times as far from the Sun as Saturn is!

Tycho made exceedingly accurate observations of the positions of the planets, and in his *Epistolarum Astronomicarum* (Astronomical Letters, Uraniburg, 1596), shown in the exhibit, many of these observations are printed. After his death in 1601, his pupil Kepler used these observations to discover the laws of motion of the planets.

Copernicus had felt that the circle was the only suitable kind of curve for a planet's motion, hence his system was made up of circles. But there were certain irregularities which made it necessary for combinations of circles to be used for the motions. In all, there were in the system of Copernicus 34 circles to explain the motions of the Moon and the six planets, Mercury, Venus, Earth, Mars, Jupiter, and Saturn.

It was Kepler who threw out these circles and produced the simple system essentially as we know it today. Using Tycho's observations of the planet Mars, Kepler announced in his *Astronomia Nova* (New Astronomy, 1609) that the orbit of each planet is, instead of a circle, an ellipse. Moreover, he said, as the planet revolves around the Sun it does so in such a way that the line joining the Sun and the planet sweeps over equal areas in equal intervals of time. So when the Earth is nearest the Sun, in January, it moves faster in its orbit than when it is farthest from the Sun, in July. It thus became unnecessary to have the cumbersome combinations of circular motions; one ellipse served for each body, and the number of motions was reduced from the 34 of Copernicus to the 7 of Kepler.

In his *Harmonices Mundi* (Harmonies of the World, Lincii, 1619), Kepler announced his third law of motion, which links the period required for a planet to revolve around the Sun and the distance of the

planet from the Sun. He was particularly delighted with his discovery of the relationship, and cried in exultation, "The die is cast, the book is written, to be read now or by posterity, I care not which. It can well await its reader; has not God waited 6000 years for an observer?"

These two epochal works of Kepler are included in the exhibit, as are also the three great works of Galileo, who corresponded with Kepler. In *Siderius Nuncius* (Sidereal Messenger, Venice, 1610), Galileo announced, among other things, his discovery of the four bright satellites of Jupiter. This was a subtle demonstration of possible truth in the Copernican theory. For, said Galileo, there are those who argue that as the Earth revolves around the Sun the Moon could not keep up with us, and would be lost. Now here was a planet with not one, but four moons, and they keep up with the planet, while the planet revolves around something else. So our Moon could keep up with us.

It was in his *Istoria e Dimostrazione* (Description and Observations of the Spots on the Sun, Rome, 1613) that Galileo first flatly stated his faith in the theory of Copernicus, and as a result he was warned not to speak or write of the theory in the future. His book, Kepler's "New Astronomy," and the masterwork of Copernicus were all put on the Index of Prohibited Books in 1613, and remained there until 1835. It is true that copies of *De Revolutionibus* were permitted to circulate if certain alterations and deletions in the text were made, but nevertheless the full text of the book was forbdiden for more than two centuries.

Galileo disobeyed the injunction to shun the Copernican theory in his *Dialogo* (Dialogue on the Two Chief Systems of the World, Florence, 1632). As a result he was forced to abjure his heresy, and to spend the remainder of his life under close control and supervision at his villa in Florence. His manuscript had been widely circulated, and he had received encouragement even from such men as Cardinal Baronius, who said, "The intention of the Holy Ghost is to teach us not how the heavens go, but how to go to heaven." But some of the words spoken by a simple-minded character in the book were almost direct quotations of Pope Urban VIII, and such disrespect could not be condoned.

In the *Almagestum Novum* (New Almagest, 1651) of Giovanni Battista Riccioli there are printed the papal judgment against Galileo, and the text of his abjuration under threat of torture. Riccioli was one of the most important antagonists of the Copernican system, and his book is a very studied statement against it. The copy of the volume which is in the Fels Planetarium exhibit was owned by Isaac Newton, and contains many of his manuscript marginal notes.

Otto de Guericke answered many of the Scriptural objections to the theory in his *Experimenta Nova Magdeburgica de Vacuo Spatio* (New Experiments with the Vacuum, Amsterdam, 1672), the first 53 pages of which are astronomical. This work is in the exhibit, because it is a well-tempered treatment of the Scriptural arguments, and an answer to Riccioli.

The copy of Isaac Newton's *Principia Mathematica Philosophiae Naturalis* (Mathematical Principles of Natural Philosophy, London, 1687) in the exhibit bears the autograph and bookplate of Thomas Carlyle, who once aspired to be Astronomer Royal of Scotland. The book contains Newton's demonstrations of the law of universal gravitation, and his statements of the fundamental laws of mechanics and the motions of bodies. By means of the principles here set down, Newton was able to prove abstractly that Kepler's laws of planetary motions should be true, hence we may consider this book to constitute the end of the proof of the Copernican theory.

Almost a century and a half had passed since the publication of *De Revolutionibus,* yet there were still some doubters, and it was not until another generation had come and gone that the Copernican theory was being taught on terms equal or superior to the standing of the earth-centered Ptolemaic theory, which had held absolute sway for the fourteen centuries before Copernicus.

It is particularly fitting that the scientific world should this year honor Copernicus, the Pole, and, because of him, Tycho the Dane, Kepler the German, Galileo the Italian, and Newton the Englishman. Science is timeless and crosses all boundaries. The fury of demagogues and bigots can not stop the ceaseless flow of truth. There are some things which transcend man's thirst for temporal power.

Such an exhibit as this is a calming influence, and visitors to the Fels Planetarium have been interested in it to a degree not quite anticipated when it was assembled. It is doubtful if there is any other place in the world where a comparable exhibit is on display at this time.

Additional Note

Our local celebration also included the meeting of the Rittenhouse Astronomical Society on Friday, May 14, at which Dr. Roy K. Marshall, Assistant Director of the Fels Planetarium, spoke on "The System of Copernicus." In addition to the usual facts concerning the life and work of the Polish churchman-astronomer, Dr. Marshall described the two versions of the solar system devised by Copernicus. The first, in his *Commentariolus* (written about 1530) was slightly more awkward than his final version, which appears in the *Prima Narratio* of Rheticus (about 1540) and in *De Revolutionibus.* Many epicycles were necessary, however, even in this final version, and Dr. Marshall went on to explain that only by the work of Kepler was the last vestige of epicyclic motion removed from the system. But the imperfections existing in the theory as published by Copernicus detract little from his greatness. His was a bold conception which challenged authority and the best thought since the beginning of time; he may truly be called the first modern astronomer.

The Copernican Quadricentennial in Milwaukee

On Sunday afternoon, May 23, 1943, an audience of five hundred, mostly prominent citizens of Polish descent, gathered at the Milwaukee Public Museum to pay honor to Copernicus. The meeting was sponsored by the Pulaski Council, a prominent Polish organization, whose President, F. E. Gregorski, a well-known attorney, opened the meeting. The presiding officer was the Reverend Raphael N. Hamilton, Dean of the Graduate School of Marquette University.

"The Broken Note," a trumpet signal, opened the ceremonies. This is a symbol of the suffering of Poland, the legend being that a young trumpeter in the thirteenth century was sounding the trumpet warning from a castle wall as the Tartar horde approached, when a Tartar arrow pierced his breast in the midst of one of the trumpet notes. Following were three musical selections by the choir of the Polish church.

The principal address, "The Achievements of Copernicus Mark the Birth of Modern Science" was given by Herbert W. Cornell, a charter member and former President of the Milwaukee Astronomical Society, who holds the office of Chief Examiner and Secretary of the Milwaukee City Service Commission. Mr. Cornell began his discourse by quoting the lines from Sir Alfred Noyes' "Watchers of the Sky," depicting the spiritual insight of the astronomer:

> "I know that I am dust, and daily die,
> Yet, as I trace those rhythmic spheres of night
> I stand before the Thunderer's throne on high
> And feast on nectar in the halls of light."

After outlining the geocentric conceptions of the Egyptians, Chaldeans, and other early nations, the speaker explained the concentric spheres of Eudoxus and the epicycles of Ptolemy; ideas which were to remain as fixed in European thought until Copernicus propounded the system which we know today to be true. Using the width of the platform of the Public Museum (twenty-nine feet) as the width of the Earth's orbit, and a light in the center of the stage as the Sun, Mr. Cornell explained the difficulty faced by Copernicus in failing to detect any stellar parallax; a difficulty which he correctly explained as due to the distance to the fixed stars being so great as to render the dimensions of the Earth's orbit insignificant, and startled the audience by telling them that, as he faced the east, on the scale of the Earth's orbit fitting the width of the Museum platform, the nearest fixed star would be at Pittsfield, Massachusetts!

The visual proof of the rotation of the Earth by means of Foucault's pendulum, and the proof of the orbital revolution by means of the discovery of the aberration of light were explained, and particular atten-

tion was drawn to the explanation of the phenomenon of precession as given by Copernicus. Referring to the fact that Greece, to whose ancient philosophers we owe so much even though their doctrines were erroneous, Poland which produced Copernicus, and Holland which produced the inventors of the telescope and microscope and thereby gave the mechanical means by which science was to advance so rapidly, are today the three countries which have suffered the most from German tyranny, Mr. Cornell predicted that the spirit which produced these advances of science is not dead but will cause a greater Greece and Poland and Holland to rise from the present ruins and to give to the world new leaders in thought and new discoverers in the realm of science.

YOLANDA MAJOWSKA, *Chairman.*

The Copernican Quadricentennial in Carnegie Hall, New York

The climax of the several ceremonies held throughout the United States in commemoration of the Copernican Quadricentennial, as indicated on page 287 of the preceding issue, was reached in the exercises held in Carnegie Hall, New York City, in the evening of May 24, the exact date of the death of Copernicus four hundred years earlier.

The release issued from the Kosciuszko Foundation, under whose auspices and those of the Copernican Quadricentennial National Committee these exercises were held, gives the details of the program. Realizing that an account of the events of this occasion will be of interest to all astronomically minded persons the world over, we are giving here practically the complete release for the benefit of readers who might not otherwise have access to it.

It might seem that this account should occupy the first place in this special Copernican issue. However, conditions were such as to require the printing of the earlier pages before the date of the meeting in Carnegie Hall, hence it must appear here. It is hoped that it will not be overlooked.

The release follows.

Nine Americans and one Chinese, honored as "modern pioneer scientists," of worldwide eminence in widely varied fields of achievement in pure and applied science received Copernican Citations last night (Monday, May 24) at the close of the Copernican Quadricentennial program in Carnegie Hall, New York, which climaxed the nation-wide commemoration of the 400th anniversary of the great Polish astronomer, Nicholas Copernicus, who died in Poland, May 24, 1543, on the very day he saw

the first published copy of his epoch-making astronomical treatise, *De Revolutionibus Orbium Coelestium,* proclaiming the heliocentric laws of the solar system and revolutionizing man's outlook upon the universe.

This historic meeting in honor of the immortal Copernicus, known as "The Father of Modern Astronomy," was sponsored jointly by the Kosciuszko Foundation, and which Dr. Henry Noble MacCracken, President of Vassar College, is President, and Dr. Stephen P. Mizwa, Secretary, and by the Copernican Quadricentennial National Committee, of which Dr. Harlow Shapley, Professor of Astronomy and Director of the Harvard College Observatory, is Chairman. Dr. MacCracken welcomed the large and distinguished audience, including America's leading scientists, educators, and academicians, on behalf of the Kosciuszko Foundation, and introduced Dr. Shapley, the presiding chairman.

Dr. James R. Angell, President Emeritus of Yale University, was Chairman of the Committee on Citations. Serving with Dr. Angell on this Committee, for the selection of these "modern pioneers in science, who are recognized as having made a substantive contribution of revolutionary character in science which opened up new channels of thought in scientific research, or new ways of doing things which affect the future of mankind," are the following authorities in their respective fields of science and education: Dr. Edwin G. Conklin, Dr. Karl K. Darrow, Dr. Alan Gregg, Dr. Frank B. Jewett, Dr. Frederick P. Keppel, Dr. Henry Noble MacCracken, Dr. Henry Allen Moe, Dr. William Allen Neilson, and Dr. Harlow Shapley.

The ten men of science who received these Copernican Citations last night (Monday, May 24), either personally or by proxy, were: John Dewey of New York; Walt Disney of Burbank, Calif.; Albert Einstein of Princeton, N. J.; Henry Ford of Dearborn, Mich.; Ernest Orlando Lawrence of Berkeley, Calif.; Thomas Hunt Morgan of Pasadena, Calif.; Igor I. Sikorsky of Stratford, Conn.; Wendell Meredith Stanley of Princeton, N. J.; Orville Wright of Dayton, Ohio; and James Y. C. Yen of Chungking, China.

These diplomas of the Copernican Citation were designed and embellished by Arthur Szyk, famous Polish artist and illuminator, and were signed by Dr. Henry Noble MacCracken, as President of the Kosciuszko Foundation, and by Dr. Harlow Shapley, as Chairman of the Copernican Quadricentennial National Committee, and by Dr. James R. Angell, as Chaiman of the Committee on Citations. The general text of the Coperican Citation read: "Bestowed in the name of the Kosciuszko Foundation on recommendation of a Committee on Citations selected from the Copernican Quadricentennial National Committee," and they were dated New York, May 24, 1943. Following

are the individual texts of citation for each of the ten honored scientists:

JOHN DEWEY: "A single-minded sage who has stimulated and enriched the thinking of his time in education, philosophy, and in all the arts of life, proclaiming everywhere the truly vital nature of thought as reality in the making."

WALT DISNEY: "Whose animated cartoons, with their highly original use of sound and color and their gay anthropomorphic humor, have delighted audiences the world over."

ALBERT EINSTEIN: "Whose revolutionary concept of space, time and energy has transformed both science and philosophy."

HENRY FORD: "Whose sturdy independence of mind, tenacity of honest purpose and relentless frugality of method, has enriched the people with a new freedom and opened a new horizon to manufacture."

ERNEST ORLANDO LAWRENCE: "Inventor and builder of the most powerful engine of transmutation of the elements, organizer and chief of the greatest contemporary school of nuclear physics."

THOMAS HUNT MORGAN: "Author of a revolution in our knowledge of the causes and mechanisms of inheritance."

IGOR I. SIKORSKY: "Pioneer aeronautical engineer, who has created a heliocopter of revolutionary implications and given new freedom of movement in the air."

WENDELL MEREDITH STANLEY: "Discoverer of a crystalline protein having all the characteristics of a disease-producing virus, a concept revolutionary for the study and control of virus diseases."

ORVILLE WRIGHT: "A modern, this time successful Icarus, who fashioned wings for man and showed him how to navigate the ocean of the air."

JAMES Y. C. YEN: "Illustrious inventor of a simple, easily mastered system of written Chinese whereby the book of knowledge has been opened to millions of previously illiterate minds, a leader of his great people in applying scientific methods to the enrichment of their soil and the increase of the fruits of their toil."

The ceremony of citation, conducted by Dr. Shapley, was witnessed by a distinguished audience of scientists, educators, research specialists, directors of astronomical observatories and planetariums, and amateur astronomers, and included a large representation of leading Polish-Americans in the metropolitan area, and many members of the Polish Catholic clergy. Among the prominent box-holders were the members of the Copernican Quadricentennial Commission of the State of New York, recently created by act of the New York State Legislature, with the approval of Governor Dewey, and with the appointment of Hon. Charles O. Burney, Jr., and Hon. Philip P. Baczkowski of Buffalo as Chairman and Vice-Chairman of the Commission, for yesterday's (May 24) statewide observance of Poland-Copernicus Day.

Following is the program of scientific and musical tribute to Copernicus, as presented last night (May 24) in Carnegie Hall, New York:

COPERNICAN QUADRICENTENNIAL PROGRAM

"Dzwon Zygmunta" (Tolling of the King Sigismund Bell or Liberty Bell) from the Cathedral of the Wawel, Krakow;

"Hejnal" (The "Broken Note Signal" of the Trumpeter of Krakow, 1241);

National Anthems of the United States and Poland, sung by the Schola Cantorum of New York, under direction of Hugh Ross;

Opening Remarks, by Dr. Henry Noble MacCracken, President of Vassar College and of the Kosciuszko Foundation;

Introductory Message by the Presiding Chairman, Dr. Harlow Shapley, Director of Harvard College Observatory, President of the American Academy of Arts and Sciences and of the National Society of the Sigma Xi;

Message of the President of the United States, read by Dr. Shapley;

Message of the President of the Republic of Poland, delivered by His Excellency Jan Ciechanowski, Polish Ambassador to the United States;

Greetings from Sir Henry Hallett Dale, President of the British Royal Society of London;

Address, "On Behalf of American Astronomers," by Dr. Joel Stebbins, Professor of Astronomy and Director of Washburn Observatory at the University of Wisconsin, and President of American Astronomical Society;

Address, "On Behalf of American Catholic Scholarship," by the Reverend Professor Michael J. Ahern, S.J., Senior Professor of Science at Weston College, Mass.;

Group of Ancient Polish Dances on the Harpsichord, by Madame Wanda Landowska—"Chorea Polonica" by Diomedes Cato (1570-1607), "Volta Polonica" and "Wyrwas" (Anonymous, 1615), "Polonaises in C Minor and F Major" by Prince Michael Cleophas Oginski;

Greetings, "On Behalf of the Scholars of Poland who have been temporarily silenced," and an Address on "The Polish Golden Age in the Era of Copernicus," by Dr. Oscar Halecki, Professor of History at the University of Warsaw, Poland, and Director of the Polish Institute of Arts and Sciences in New York;

Violin Solos by Bronislaw Huberman, with Boris Roubakine as piano accompanist—"Air for Four Voice-Parts" by Henricus Finck (1445-1527), contemporary of Copernicus; "Valse, Opus 64 No. 2" by Frederic Chopin; and "La Fontaine d'Arethuse, from Myths, Opus 30," by Karol Szymanowski;

Address on "Nicholas Copernicus, The Founder of Modern Astronomy," by Dr. Edward Rosen, Instructor in History at the College of the City of New York, and Copernican Scholar;

"Gaude Mater Polonia,"—Thirteenth Century Polish Hymn and Alma Mater Song of the University of Krakow, since the student days of Copernicus, sung by the Schola Cantorum of New York, with Hugh Ross conducting, and arranged especially for the Copernican Quadricentennial by Karol Rathaus, Professor of Music at Queens College;

Copernican Citations, with names announced, individual citations read, and diplomas presented by Dr. Shapley.

Following are brief excerpts from the introductory remarks by Dr. Henry Noble MacCracken and Dr. Harlow Shapley and Dr. Joel Stebbins, and the complete text of the letter of congratulation on the Copernican Quadricentennial, which was written by President Roosevelt, and sent to Dr. Harlow Shapley, to be read at last night's commemorative occasion in Carnegie Hall (Monday, May 24):

Dr. MacCracken said in part as follows: "Ought we to celebrate Copernicus? Has science anything to do with popular applause? Shall we make 'propaganda' out of this Polish cleric, who died in obscurity four hundred years ago? The answer is yes, to all these questions. We Americans ought to celebrate the first modern astronomer, his book, and the birth of modern science, because we of the New World are the children of the new geography and astronomy, of navigation and discovery. Not to celebrate Nicholas Copernicus would be indeed ungrate-

ful. Science has something to do with popular applause, for science belongs not to the scientist alone, but to the people. Never again shall science be shut in a tower, for hermits to speculate upon, or tyrants to monopolize. Science exists for the good of mankind. We will use our memories of this Polish scholar, Nicholas Copernicus, his life and his book, that we may never forget that a scholar may also be a patriot, that the revolutionary mind, breaking new ground for discovery, is not to be forgotten in world history, and that we may remind ourselves that knowledge is international, the possession of no one people, and that the sufferings of the martyr universities of Poland, where once Copernicus studied, shall be the fruitful seed of new truth in time to come."

Dr. Shapley said in part: "We are here tonight to renew our communal pledge of faith in human civilization. We are here to commemorate one particularly bold example of the freedom of thought and of exploratory imagination; and, in memorializing that one bold thought, we praise all similar adventures of the human intellect. We are here, as men and women have gathered this month in similar ceremonies in scores of cities and towns, to record that our day and our age is receptive to all revolutionary contributions to knowledge. We recognize that the small, steady, practical additions to our intellectual wealth are most significant. . . Even when we must consider an abrupt challenge to settled ideas, contradictions to the conveniently pleasant, the overthrow of the long-sanctioned dogma—we register by our congregation here that we shall be friendly to such revolution, friendly to the freedom for concepts that become essential to our reorientation.

"Once Copernicus had established the reasonableness of the heliocentric hypothesis, he began to shake men's minds free from the static of a fixed Earth. Slowly the cramping, self-assumed importance of man in the universe was diminished. It became gradually less difficult to follow with joyous heart the exploration of space, time, matter, and mind. . . It is in the name of this spirit that we are here assembled. We are all active participants in a great pledge. For I submit that it is as much by our presence here, as by our words and deeds, that we consecrate this occasion. *De Revolutionibus Orbium Coelestium* dealt with more than planets and celestial mechanics. That volume dealt, by implication, with the evolution of certain terrestrial bodies,—namely ourselves—with the evolution of our minds and of our grasp of physical reality. To this spirit of freedom on your behalf I dedicate these ceremonies."

Dr. Joel Stebbins said in part: "The astronomers of America are glad to join in an appreciation of Copernicus. The system which he expounded is so fundamental and has been taken for granted for so long, that it requires an occasion like the present one to remind us that there was ever a question of the Earth revolving about the Sun. We in our time have also been passing through a change just as revolutionary and per-

haps as little noticed as when the Polish churchman quietly jolted us out of our fixed and privileged position at the center of the universe.

"Less than twenty-five years ago, astronomers were debating: how large is the galaxy, and are there other galaxies outside of our own. There is now general agreement on these points. The galaxy is estimated to be 100,000 light years in diameter. (Remember that one light year is equal to six *million million* miles.) The Sun is more than half way from the center to the outside. There are many other independent galaxies, each composed of millions of stars. We have the astronomical multiplication table: a thousand million stars make one galaxy, a thousand million galaxies make one universe. Copernicus gave us about 20 miles per second for the Earth's motion about the Sun, but the Sun moves at 200 miles per second about the center of the galaxy, and even at this speed it requires 200 million years to complete the circuit. Where the galaxy as a whole is going, we do not know.

"Although, beginning with Copernicus, first the Earth, then the Sun, and finally the whole galaxy has been shifted from the center of the universe, astronomers cling to the idea that the system of planets revolving about the Sun is a rare one, if indeed it is not unique, and the Earth stands out among these planets. Even if there are dark bodies revolving about other stars, the number supporting life as we know it must be relatively small at any one time. The last two thousand years of civilization are only the one-millionth part of the history of the Earth, hence, of all the bodies anywhere which might be like the Earth sometime, only one in a million would be like us now. The Sun is an ordinary star, in an ordinary place, in an ordinary galaxy, but we still believe that Copernicus lived on an extraordinary planet, at an extraordinary time, and, needless to say, he was an extraordinary man."

President Franklin D. Roosevelt sent the following message congratulating the Copernican Quadricentennial, from the White House, which was read at the Carnegie Hall meeting by Dr. Harlow Shapley, Chairman of the Copernican Quadricentennial National Committee. President Roosevelt wrote as follows to Dr. Shapley:

"Commemoration of the quadricentennial of the death of Copernicus naturally turns our thoughts to his native Poland, now in chains and prostrate under the evil power of Axis conquest. Poland's plight today is indeed tragic. Her oppressors are likewise the implacable foes of truth, progress, and the spirit of free inquiry to which Copernicus devoted all of the years of his active and singularly useful life.

"Although free institutions are suppressed temporarily in the land of Copernicus's birth and in other once happy lands, the dawn of a happier day is assured. It is therefore highly appropriate that in the midst of all-out war and the sacrifices which it demands, we pause a moment to draw refreshment of mind and spirit by recalling the great contribution which

Copernicus made to the sum of human knowledge and to the progress of mankind.

"Not only must great men and great nations be allowed to attain freedom. Liberty must be made progressively available to small states, to communities, and to the individual himself if humanity is to march forward into light and life. We must always remember that the creation and sweep of great liberalizing ideas may be the work of a single isolated individual, as it was in the case of Copernicus.

"By these reverent ceremonies, therefore, the people of America honor not only a great pioneer of our civilization, they recognize thereby the undying contributions that have come from the small nations of the world. Copernicus serves to remind us that small nations have given for the common advantage of all peoples many of the great enduring concepts which have enriched the life of man. This opportunity of living with the growing and unrestricted knowledge about man and his place in the univese lays on all of us so imperious a responsibility that we should pledge ourselves in the name of all venerated great men of ideas to strive to maintain that opportunity forever. Very sincerely yours, FRANKLIN D. ROOSEVELT."

The Planets in July and August, 1943

By ALICE H. FARNSWORTH

NOTE: Greenwich Civil Time is used unless otherwise stated. To obtain Eastern Standard Time subtract 5 hours; Central Standard Time, 6 hours, etc. War Time in each zone is one hour later than Standard. Phenomena are described as seen from latitude 45° N. *The American Ephemeris and Nautical Almanac* is the source of the data.

Sun. The Sun traverses much of Gemini, all of Cancer, and half of Leo during the summer months. It moves from $\alpha\ 6^h\ 36^m.1$, $\delta +23°\ 11'.1$ on July 1 to $8^h\ 41^m.2$, $+18°\ 18'.1$ on August 1, to $10^h\ 37^m.5$, $+8°\ 41'.2$ on September 1. July 4 is the date when the Earth is farthest from the Sun. As a consequence the solar diameter appears 3 per cent smaller than it does in January, and the Earth's motion in its orbit is slower than at any other time of year.

Moon. Phenomena are as follows:

		h	m
New Moon	July	2	12 44
First Quarter		10	16 29
Full Moon		17	12 21
Last Quarter		24	4 38
Runs high		2	13
In apogee		4	22
Runs low		16	14
In perigee		17	22
Runs high		29	20
New Moon	August	1	4 6
First Quarter		9	3 36
Full Moon		15	19 34
Last Quarter		22	16 4

	h	m
New Moon	30	19 59
In apogee	1	3
Runs low	13	1
In perigee	15	8
Runs high	26	2

The 4-day waxing crescent Moon occults Venus on the morning of July 6. August brings New Moon twice during the month.

Eclipses. In August comes the second eclipse season of the year, the Sun being near the current position of the ascending node of the Moon's orbit, in Cancer. Two eclipses occur, the minimum number at a node-passage when both umbral and penumbral phenomena of Earth's and Moon's shadows are taken into account.

On August 1, an *annular* eclipse of the Sun occurs over the ocean south of Australia. Near its mid-point the path of annularity lies off the southwest tip of the Australian continent. On August 15, a *partial lunar* eclipse occurs, visible largely in the Earth's eastern hemisphere. Seven-eights of the Moon's diameter will be covered by the Earth's shadow at mid-eclipse.

Maps and further details of both eclipses were given in the January, 1943, issue of POPULAR ASTRONOMY. Neither eclipse is visible from North America.

Mercury throughout July is lost in the brilliance of the Sun's rays. It reaches superior conjunction on July 18, moving from the west to the east side of the Sun. Four days after, it passes Jupiter. It comes to greatest elongation east of the Sun on August 29, difficult to see at this season when its path makes a small angle with the horizon.

Venus exhibits this summer its most interesting changes as seen in the telescope. During the two months its apparent diameter more than doubles while its waning crescent phase becomes ever more marked. It reaches greatest brilliancy on July 31, when its phase resembles a 5-day Moon. During July and early August it should be easy to find with the naked eye even in broad daylight. The simplest method of finding it is to locate it with the telescope by means of setting circles ($\alpha\ 11^h\,06^m$, $\delta\ +3°.0$ on July 31), then sight over the tube until it is seen as an inescapable bright mote on a blue sky. Without a telescope, the Moon may serve as guide to it on July 6 by allowing the Moon half a degree of eastward motion during each hour subsequent to the occultation.

On July 6 Venus, the Moon, and the bright star Regulus will all be close together on the celestial sphere. In the British Isles, planet and star will be occulted about half an hour apart in mid-afternoon. In the eastern United States the occultation of Venus will occur low in the eastern sky in the forenoon (See Occultation Predictions, p. 334).

Mars moves eastward from Pisces, through Aries, into Taurus. It is a "morning star," rising before midnight in August. It reaches western quadrature on August 24.

Jupiter is unfavorably placed for observation, reaching conjunction on July 30, in Cancer.

Saturn remains in Taurus and rises before the Sun. During August it will be once more accessible with the telescope, in the latter part of the night. As shown in the chart of its motion (Figure 3, page 34 in this year's January issue of POPULAR ASTRONOMY) the planet passes just north (52′) of ζ Tauri on August

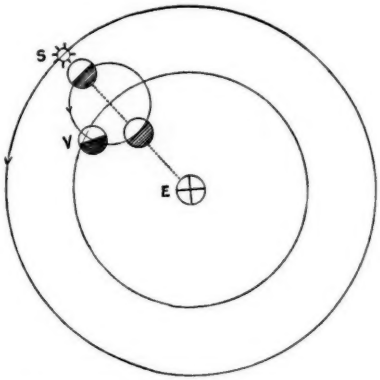
15. On its return trip in December it will be slightly closer.

Uranus comes up before sunrise. Its path lies half a degree south of κ Tauri. Its position on August 1 is $\alpha\ 4^h\ 25^m$, $\delta +21°.5$.

Neptune's motion in Virgo carries it eastward only 5^m during this period. Its average position for the month ($\alpha\ 12^h\ 01^m$, $\delta +1°.3$) may be verified by reference to Figure 5 on page 35 of POPULAR ASTRONOMY for January, 1943. (Erratum: On this chart the co-ordinates in declination should read, in order from top to bottom: $+1°\ 30'$, $+1°\ 0'$, $+0°\ 30'$, $0°\ 0'$.)

Did any one make the comparison between Neptune and the star BD $+11°\ 2656$ suggested on page 92 of the February issue? On April 2, with power 95 on the 8-inch equatorial, the planet showed a fainter, decidedly greenish, more stable image than the neighboring yellowish seventh-magnitude star (class F2, Mag. 7.00 on Harvard P_V system).

Venus receives special consideration this summer, as the only bright planet available for study in the evening. At an unknown early period it came to be realized that Phosphor in the morning and Hesper in the evening sky were indeed one and the same planet. In the Ptolemaic scheme of the planetary system, Venus, like Mercury, was made to move in its synodic period of 584 days once around its epicycle (See Figure). Meanwhile the center of the epicycle kept



MOTION OF VENUS ACCORDING TO THE PTOLEMAIC SYSTEM.

The smallest circle is the epicycle, around which the planet (V) moves in its year of phases. The center of the epicycle remains on the line joining the stationary Earth (E) to the annually revolving Sun (S).

pace with the supposed yearly revolution of the Sun around the stationary Earth, the center of the epicycle remaining always on the line joining Sun to Earth. By this combination of motions the swinging of the planet to a limited distance alternately east and west of the Sun was satisfactorily represented. Consideration of the diagram shows that under this arrangement the planet could at no

time present to the Earth more than half its illuminated hemisphere, all its light coming from the Sun. This fact constituted no obstacle to the theory in times when the eye was the only available optical instrument.

During this year of 1943 in widespread quadricentennial ceremonies we commemorate Copernicus, that versatile Polish scholar and statesman who perceived and advocated a great simplification in the theory of planetary motions: *viz.*, Keep the Sun stationary and let the Earth and other planets move around it; the Earth completing a revolution in one year, and rotating once daily on its axis.

Imagine Galileo's excitement, in the autumn of 1610, sixty-seven years after the publication of Copernicus' *De Revolutionibus Orbium Coelestium*, when as the months went by he was able to watch Venus change from gibbous to crescent phase, proving not only that it receives its light from the Sun, but revolves around it. Here was ocular demonstration of the inadequacy of the Ptolemaic system, promptly announced, such was the temper of the times, at first in the form of the anagram,

Haec immatura a me iam frustra leguntur: o.y.

Later, these letters properly re-arranged revealed that Galileo had by observation confirmed a necessary consequence of the theory of Copernicus, *viz.*,

Cynthiae figuras aemulatur Mater Amorum

which is to say

The Mother of the Loves [*i.e.*, Venus] imitates the phases of Cynthia [*i.e.*, the Moon].

Modern telescopes are better than Galileo's. What details do they reveal on the surface of Venus? So little do they reveal on its silvery-white surface that we are actually still uninformed as to the period of axial rotation of this "twin" of Earth which comes closer to us than any of the principal planets. The spectroscope,[1] through the absence of any Doppler slant of the lines, rules out an Earth-like short period (less than 6 days), temperature measurements[2] of the night and day sides of the planet reveal a similarity judged incompatible with its keeping the same face always sunward (*i.e.*, one rotation in 225 days). Possibly it rotates eight or ten times during one revolution around the Sun.

To the eye the surface has occasionally presented irregularities in the terminator and hazy areas hardly considered authentic. On Ross's red-sensitive plates no details show; in ultra-violet photographs weak impermanent dark bands appear, in general perpendicular to the terminator.[3] Evidently the visible surface is a cloud layer. The slow decline in the light of a star occulted by Venus (July, 1910), the extension of the cusps beyond an arc of 180°, the appearance of a complete luminous ring around the planet on entering the Sun's disk at transit, and indeed at inferior conjunction when planet and Sun were separated by as much as 2½° (1922) all give evidence of a deep atmosphere surrounding the planet.

The composition of this atmosphere down to such levels as the spectroscope can probe reveals no oxygen or water vapor, but a relatively huge amount of carbon dioxide.[4] The difficulty of supposing heavy clouds to exist where no water vapor can be detected was pointed out and resolved by Wildt.[5] The assumption that Venus (unlike the Earth) was for some unknown reason poorly supplied with water vapor in the beginning, points to a dearth of the free oxygen which on Earth eventually formed an ozone layer protecting the surface from the Sun's ultra-violet radiation (of wave-length shorter than 2900 A). Carbon dioxide

with water vapor on Venus could thus under the action of ultra-violet radiation react to form formaldehyde and oxygen according to the relation

$$CO_2 + H_2O \rightarrow CH_2O + O_2$$

Under the blanketing effect of carbon dioxide the surface of Venus below the clouds may be supposed to be at or over the boiling point of water.[6] The oxygen from the above reaction may be employed in erosion which would be rapid at this temperature. That careful spectroscopic research fails to reveal on Venus the presence of the other product, formaldehyde gas, is attributed to the fact that at such temperatures the gas is stable only if absolutely dry. A small amount of water vapor present would cause precipitation of a sort of "formaldehyde snow" in dense white clouds. Moreover this solid is known not to vaporize at the probable temperature of the upper surface of the clouds on Venus.

To ponder these considerations, as one watches this planet brilliant with sunshine reflected possibly from vast stretches of formaldehyde snow, is to find Venus no longer twin to the Earth, but rather an object of unique interest in the Sun's family.

References

[1] Dunham, *Pubs. A.S.P.*, **51**, 264, 1939.
[2] Pettit and Nicholson, *Pop. Astron.*, **32**, 614, 1924.
[3] Ross, *Ap. J.*, **68**, 57, 1928.
[4] Dunham, *ibid*, p. 271.
[5] Wildt, *Ap. J.*, **92**, 247, 1940.
[6] Wildt, *Ap. J.*, **91**, 266, 1940.

Asteroid Notes

By HUGH S. RICE

From about June 15 to August 15, Juno and Iris are the best asteroids available for observation. The next one is Pallas, which is in a position to be picked up with a telescope in late summer and during the autumn. Then planets 12 Victoria and 216 Kleopatra follow. Finally, 27 Euterpe, Vesta, and Ceres come to opposition in December and can be observed and followed during the winter months.

Juno is retrograding in Aquila and comes to opposition with the Sun on July 13. On June 15 (0^h UT) it is 4° southeast of ι Aquilae. On July 1, it is ½° north of the star 42 Aquilae. On July 21, it passes by 26 Aquilae, just north of the star. On August 8 it is 2° south of λ Aquilae, and on August 19 it is 2° south and ¾° east of η Scuti. Juno is here immersed in the Milky Way, and while observers are directing their instruments to this region, they will likely observe Messier 11 (NGC 6705), a fine star cluster in Scutum, west of the star η, and also HI 47 (NGC 6712), a beautiful globular cluster, which is 2¼° south and a bit east of M 11. There are also various other worthwhile objects in this general area of the sky. The average magnitude of Juno at various oppositions is 8.7.

The asteroid 7 Iris is at opposition on August 20. On June 15 it is 2¼° west and a bit north of the star 44 Aquarii. On June 25 it is about 1° north of 44. It is moving east and north to its stationary point which it reaches shortly before the middle of July. On July 16 it is less than 1° south of α Aquarii, and on

July 30 it is almost in coincidence with a 6th-magnitude star 1¼° nearly west of α Aquarii. From this position Juno goes westward until on August 14 it is less than 1° due south of 32 Aquarii. The average magnitude of Juno at various oppositions is 8.4.

The ephemeris of Juno given here was computed by Dr. Paul Herget of the Nautical Almanac Office, and that of Iris was computed at the Yale University Observatory. Both are reproduced by the courtesy of Dr. Dirk Brouwer of Yale.

ASTEROID EPHEMERIDES FOR 0^h U.T. EQUINOX OF 1943.0

	3 JUNO			7 IRIS		
		α	δ		α	δ
1943		h m	° ′	1943	h m	° ′
June	15	19 45.5	−4 16	June 15	22 11.8	−5 20
	20	19 42.6	−4 12	20	22 14.5	−4 45
	25	19 39.3	−4 12	25	22 16.7	−4 12
	30	19 35.6	−4 16	30	22 18.2	−3 42
July	5	19 31.5	−4 24	July 5	22 19.2	−3 14
	10	19 27.2	−4 36	10	22 19.4	−2 50
	15	19 22.8	−4 52	15	22 19.0	−2 30
	20	19 18.4	−5 11	20	22 17.8	−2 13
	25	19 14.0	−5 34	25	22 15.9	−2 1
	30	19 9.8	−6 0	30	22 13.3	−1 54
Aug.	4	19 6.0	−6 28	Aug. 4	22 10.1	−1 51
	9	19 2.6	−6 58	9	22 6.3	−1 53
	14	18 59.6	−7 29	14	22 2.0	−2 0

Hayden Planetarium, American Museum of Natural History, New York City, May 21, 1943.

Occultation Predictions for July and August, 1943

(Taken from the *American Ephemeris*)

Date 1943		Star	Mag.	IMMERSION Greenwich C.T.	IMMERSION a	IMMERSION b	IMMERSION Angle E from N	EMERSION Greenwich C.T.	EMERSION a	EMERSION b	EMERSION Angle E from N
				h m	m	m	°	h m	m	m	°
OCCULTATIONS VISIBLE IN LONGITUDE +72° 30′, LATITUDE +42° 30′											
July	6	Venus	−4.0	14 3.2	−0.1	+0.9	110	15 12.0	−0.5	+1.4	271
	11	80 Vir	5.8	3 56.0	..	..	30	4 8.4	..	..	8
	15	166 B.Oph.	6.5	6 36.2	..	..	16	6 51.3	..	..	349
	16	15 Sgr	5.4	1 36.3	−1.4	+0.4	108	2 49.8	−1.8	+0.4	265
	16	21 Sgr	5.0	6 57.6	−0.7	−0.3	56	7 53.2	−0.9	−1.9	296
	19	45 Cap	5.9	10 26.2	−0.4	+0.1	44	11 20.5	−0.6	−1.5	275
	25	B.D.+10°401	6.2	6 22.3	−0.1	+1.9	59	7 24.5	−0.6	+1.6	257
	28	119 Tau	4.7	7 3.8	..	..	358	7 12.9	..	..	339
	28	120 Tau	5.5	7 17.6	+0.5	+2.0	46	8 5.9	−0.2	+0.8	290
Aug.	8	13 Lib	5.8	23 53.5	−1.8	−0.7	95	1 10.5	−1.4	−1.9	307
	12	128 B.Sgr	6.4	23 23.6	..	..	166	23 47.3	..	..	205
	13	36 Sgr	5.1	5 16.9	−1.1	−0.8	83	6 22.5	−0.7	−1.1	262
	19	26 Cet	6.2	8 56.7	−1.5	+0.6	59	10 12.4	−1.4	0.0	245
	22	*f* Tau	4.3	3 40.2	+0.4	+1.9	45	4 30.0	−0.1	+1.1	278
	23	70 Tau	6.4	5 17.5	0.0	+1.6	76	6 17.6	−0.3	+1.7	249
	23	θ^1 Tau	4.0	6 54.5	−1.5	0.0	128	7 31.3	+0.2	+3.8	194
	75	75 Tau	5.3	7 0.4	0.0	+2.9	29	7 52.4	−1.5	+0.4	293
	23	264 B.Tau	4.8	7 57.0	−1.6	+0.8	107	8 58.7	−0.8	+2.8	214
	23	α Tau	1.1	11 51.1	..	..	143	12 26.5	..	..	189
	25	71 Ori	5.2	8 57.8	−1.4	+0.3	119	9 56.1	−0.7	+3.0	221

OCCULTATIONS VISIBLE IN LONGITUDE +91° 0′, LATITUDE +40° 0′

July	6		Venus	−4.0	..	..	..	..	..	15	4.4	0.0	+1.2	273
	11	80	Vir	5.8	3	29.5	−1.7	0.0	57	4	11.4	−0.6	−3.4	348
	16	16	Sgr	6.0	1	13.6	−1.5	+2.1	59	2	5.3	−0.7	−0.4	320
	16	15	Sgr	5.4	1	17.9	−0.5	−0.1	133	2	14.6	−1.6	+1.5	246
	16	21	Sgr	5.0	6	39.0	−1.3	+0.5	46	7	33.6	−1.8	−2.1	309
	19	45	Cap	5.9	10	15.9	−0.5	+1.2	25	11	5.7	−1.6	−2.0	290
	25	B.D.−10°401		6.2	6	20.0	+0.3	+1.8	54	7	13.9	−0.1	+1.3	267
Aug.	13	36	Sgr	5.1	4	52.2	−1.6	−0.2	74	6	5.7	−1.5	−1.1	275
	19	26	Cet	6.2	8	26.6	−1.3	+1.9	40	9	40.7	−2.0	+0.1	261
	23	θ^1	Tau	4.0	6	38.4	+0.5	+2.1	11	7	26.2	+0.1	+2.5	214
	23	θ^2	Tau	3.6	6	56.8	..	..	153	7	6.0	..	..	172
	23	75	Tau	5.3	7	0.2	+0.9	+3.9	7	7	26.0	−1.3	−0.8	318
	23	264	B.Tau	4.8	7	36.7	−0.5	+1.4	90	8	39.8	−0.5	+2.1	232
	23	275	B.Tau	6.5	9	28.8	−2.2	−0.4	123	10	16.3	−0.3	+4.0	198
	23	α	Tau	1.1	11	0.2	−2.9	−1.4	124	11	53.4	−1.0	+4.2	199
	25	71	Ori	5.2	8	40.7	−0.4	+1.0	104	9	40.0	−0.3	+2.2	235

OCCULTATIONS VISIBLE IN LONGITUDE +120° 0′, LATITUDE +36° 0′

July	11	80	Vir	5.8	2	26.5	−2.2	−0.7	107	3	51.7	−1.6	−1.9	311
	15	166	B.Oph	6.5	5	9.2	..	..	39	5	47.7	..	..	344
	16	21	Sgr	5.0	5	38.5	−2.2	+1.5	56	6	42.3	−1.9	−1.2	312
	16	108	B.Sgr	6.5	11	2.1	−1.6	−3.0	141	11	35.1	+0.4	+1.4	206
	20	70	Aqr	6.2	12	3.5	−2.1	−0.5	91	13	9.5	−0.9	+1.0	215
	25	B.D.+11°445		5.9	11	28.6	−0.4	+2.9	29	12	29.5	−1.9	+0.5	281
Aug.	12	16	G.Sgr	6.5	7	15.1	−1.4	−0.7	84	8	25.6	−1.0	−1.2	272
	13	36	Sgr	5.1	3	53.9	−2.0	+0.8	81	5	13.3	−2.1	−0.2	281
	19	26	Cet	6.2	7	53.5	−0.2	+3.6	7	8	32.6	−2.2	−0.4	301
	23	275	B.Tau	6.5	8	56.1	−0.3	+1.1	94	9	53.8	−0.2	+2.1	229
	23	α	Tau	1.1	10	7.8	−0.8	+1.2	92	11	14.0	−0.7	+2.2	229

The quantities in the columns *a* and *b* are given for the purpose of making these predictions useful for any place within 200 miles of the point indicated. The procedure is as follows: Subtract the longitude of the point given from the longitude of the place in question; multiply the result in degrees, taking the signs into account, by the quantity under *a* for the star to be observed; similarly, with the latitude, using *b*; apply the sum of the products, with its proper sign, to the Greenwich C.T., and obtain the predicted Greenwich Civil Time for the phenomenon at the place of observation. To obtain Eastern Standard Time it is necessary to subtract five hours; Central Standard Time, six hours, etc.

Comet Notes

By G. VAN BIESBROECK

COMET 1943*a* (OTERMA). On April 17 the Central Bureau of Astronomical Telegrams at Harvard College received information of the discovery of an unexpected comet by Miss L. Oterma at the Turku (Finland) Observatory. The following data were made available:

1943 April 8 at 21^h U.T. Magnitude 15
Right ascension 12^h 19^m Declination +1° 12′
Daily motion 36^s west 4′ north.

Through the now unavoidable delays in transmission, by the time this information reached this country the full Moon made observations on this faint object, which is located close to the ecliptic, impossible. It was not until May 1 that G. Hall, using the 24-inch reflector of the Yerkes Observatory succeeded in pick-

ing up the object and his results are recorded as follows:

1943 U.T.	α	δ	
May 1.11264	$12^h 9^m 5^s.8$	+2 25 10	Hall-Yerkes
3.11500	8 31.3	28 57	Hall-Yerkes
7.31674	12 7 20.8	+2 36 38	Nagtegaal-Lick

The comet appears as a nearly round coma without indication of tail, and both observers still record it as being of magnitude 15. The slow motion indicates that the comet is quite remote and it will be some time before a reasonable forecast of its future course can be made. So far there is no indication the object is brightening up so it may continue to require powerful telescopes for further investigation.

The name of Miss Oterma has lately become familiar in comet literature. Her work at the Turku Observatory consists in following asteroids with a large field photographic telescope. Last year she got credit for two comet discoveries in the course of that program of work.

Aside from this new comet two other previously observed ones have been followed last month. COMET 1942 *f* (WHIPPLE) has now dropped below naked-eye visibility but will remain in reach of moderately sized telescopes for some time as can be seen from the following ephemeris supplied by the discover.

1943	h m	° ′	Mag.
June 5	13 15.8	+19 41	9.7
13	22.5	16 50	10.1
21	29.7	14 9	10.5
29	13 37.3	+11 39	10.9

In the beginning of May the actual intensity was about one magnitude brighter than is indicated by the ephemeris which places the object a few degrees southwest of Arcturus in June.

COMET 1942 *e* (OTERMA) has lost considerably in brightness since last month and the increasing distance will soon put an end to the visibility.

Williams Bay, Wisconsin, May 13, 1943.

METEORS AND METEORITES

Meteor Notes from the American Meteor Society

By CHARLES P. OLIVIER, President

The Eta Aquarid meteors of May have so far been reported by two of our members. R. M. Dole at Cape Elizabeth, Maine, on 1943 May 5/6, from 14:00 to 15:00, F = 1.0, observed 18 meteors, 16 being Aquarids; on May 6/7, from 14:30 to 15:00, F about 0.3, 2 Aquarids; and on May 7/8, 13:00 to 14:00, F = 1.0, 9 Aquarids. Radiants were derived by me from his maps as follows:

		α	δ	
A.M.S. No. 1953	May 5.81	332°.5	−0°.5	14 meteors, good
1954	7.81	334.5	0.0	7 meteors, good
By Gordon Green:				
1955	4.85	335.	−1.	3 meteors, fair

The latter, now in the U.S.A. Engineer Corps, and stationed at Lancaster, Pa., was able to observe on May 4/5 from 14:00 to 15:48, F = 1.0, except inter-

ference by dawn during the last half hour. In this interval 11 meteors were seen, 5 plotted, and 8 of the 11 were Aquarids. From 3 of these the above radiant was derived. Unusually cold weather in these regions dampened the enthusiasm of several people who had previously planned to observe. Of course, other reports from a distance may yet arrive.

The Chicora (Butler County, Pa.) Meteorite

The above is the title of No. 3111 Proceedings of the U.S. National Museum, issued in 1941, the authors being F. W. Preston, E. P. Henderson, and James R. Randolph. It contains a full 30-page account of this meteor and its accompanying phenomena. My own contribution consisted in sending to the authors various reports which came into my hands, this fact being duly acknowledged by them. My purpose in writing these remarks is to discuss briefly the train drift, as the data described it, and to add my own calculations on the radiant and parabolic orbit of the meteor, neither of which was given in the publication mentioned. This meteor is my No. 1253 in F.O.R. No. 60, and the preliminary data there need certain modifications. In No. 60 the direction of train drift is given as towards 90°-azimuth, without heights. In No. 3111 the authors deduce that the enduring part of the train was about 7 km long, the top at a height of 19 km, the bottom at 16 km, and the slope 31°. Before distortion took place, the diameter was between 1.0 and 0.2 km (extreme estimates). This smoky mass expanded and drifted, but those observers who give the direction are not wholly in agreement. Weighing the reports as best I can, it now seems that 35° would fit the average better than 90°, which value was originally based on a single apparently good observation. I suggest therefore that, in No. 60, 35° be substituted for 90°, and the heights given above be entered in the proper columns. Also reference to the publication here discussed should be entered in the last column on page 119, as well as the word "stones," since two small meteorites classed as "olivine-hypersthene chondrite" have been recovered. The place they fell was at longitude 79° 44′ W, latitude 40° 56′ N. No. 3111 is in three parts and in that by James R. Randolph he calculates the necessary size of the meteor from considerations of the energy developed. I make no attempt to either analyze or criticize his surprising result which is that the mass needed was 519 tons! If this is the correct value, many opinions about the masses of fireballs would need radical correction.

Taking the altitude and aziumuth of the path in our atmosphere as given by F. W. Preston, which were $a = 33°$ and $h = 31°$, and assuming heliocentric parabolic velocity, I deduce the radiant and orbit as follows:

Radian (uncorrected) $a = 33°, h = 31°$
Zenith attraction $-8° 28'$
Radiant (corrected) $a = 33°, h = 22° 32'$; $\alpha = 145°.5$, $\delta = 19°.4$
Orbit: $i = 11°$, $\Omega = 273°$, $\pi = 255°$, and $q = 0.993$.

This indicates that the meteor overtook the Earth and had passed its perihelion point. Its small inclination perhaps indicates that most probably it was a permanent member of our Solar System. Persons interested in the subject of meteors certainly should obtain a copy of No. 3111, which has just been partially reviewed. It is a complete and carefully made study.

Fireball of 1942 September 1

This fireball crossed New Jersey in a general S.E. to N.W. direction and was observed by many in that state, by others in Pennsylvania and by a few in Mary-

land. Due to the war, doubtless, no reports from ships were received. It appeared at 11:30 E.W.T. (10:30 E.S.T.) and therefore was seen by fewer people than had it come a hour or so earlier. The collection of the data, following requests in the press, is due to my colleagues on the staffs of Cook and Flower Observatories, as I happened to be away. Hence my sincere appreciation is due to I. M. Levitt, R. K. Marshall, and S. G. Barton.

Altogether we have about 106 observations of which, as always, only a small per cent give angular coordinates for the path. The key observation was made by Howard Manlin, an amateur astronomer at Allentown, Pa., S4. He was observing variables with his telescope and turned as the brilliant light appeared. His excellent plot on a good star-map gives reliable coordinates. A number of other observers sent in rougher plots on improvised maps, or made estimates in a way to inspire confidence. On the basis of these, 6 give the (chosen) beginning point and 9 the end point. The latter I consider exceptionally well determined, the former less so. The chief uncertainty is whether the fireball did not start farther to the S.E. at a greater height. Were this supposition true, however, it would not affect the position of the radiant point derived here. The color of the meteor must have been very intense for I have never known such unanimity—nearly everyone recorded the color as blue. As to its brightness and size, it certainly had an apparent disc, sometimes noted as equal to the full Moon in size and brightness. Also several observers indoors were attracted by the light and those outside noted shadows cast. Hence there is no doubt that the fireball was both large and exceptionally brilliant. Very many report an "explosion" at the end; this should probably be interpreted as a sudden and conspicuous flare-up in brightness. The trail left was very short-lived and is variously described, the colors red and yellow being used in contrast to the blue of the head. The duration of flight, based upon 24 estimates which have an extreme range from 1 to 15 seconds, is 4.62 ± 2.78 sec. Various "sounds" are reported. Most can be explained by other noises, but as usual we find a few people saying that they heard a simultaneous "hissing" or similar sound. A few will say that it was this which called their attention to the fireball. This alleged phenomenon I, as well as others, have discussed elsewhere. Its recurrence is merely recorded here. As the end point was very low, and the fireball large, it is possible that meteorites may have fallen. The village of Lumbervilla, Pa., seems about where they would be. Some inquiry should be made in that neighborhood. The derived data follow:

Date	1942 Sept. 1; 10:30 E.S.T., P.M.
Sidereal time at end point	318°
Began over	$\lambda = 74° 04'$, $\phi = 39° 39'$, at 74.5 ± 12.0 km
Ended over	$\lambda = 75° 04'$, $\phi = 40° 24'$, at 20.8 ± 7.4 km
Length of path	128 km
Projected length of path	116 km
Observed velocity	28 km/sec
Radiant uncorrected	$a = 313°$, $h = 24°.9$
Zenith correction (parabolic)	$-1°.4$
Radiant corrected	$a = 313°$, $h = 23°.5$; $\alpha = 1°.5$, $\delta = -12°.6$

As the coordinates of the radiant might well be in error by as much as 5°, it hardly seems useful to compute an orbit.

Flower Observatory of the University of Pennsylvania, Upper Darby, Pennsylvania, 1943 May 22.

Contributions of the Society for Research on Meteorites

Edited by FREDERICK C. LEONARD
Department of Astronomy, University of California, Los Angeles

President of the Society: LINCOLN LA PAZ, Department of Mathematics, Ohio State University, Columbus
Secretary of the Society: C. H. CLEMINSHAW, Griffith Observatory, Los Angeles, and Department of Astronomy, University of Southern California, Los Angeles

Remarks on Four Notes Recently Published by C. C. Wylie

By LINCOLN LA PAZ
Department of Mathematics, Ohio State University, Columbus

ABSTRACT AND INTRODUCTION

The present communication, in so far as it relates to a note on contraterrene meteorites,[1] is simply an elaboration of certain remarks which I made extemporaneously at the time the then Secretary, Dr. Robert W. Webb, read Dr. C. C. Wylie's paper at the Eighth Meeting of the Society for Research on Meteorites held in Flagstaff, Arizona, in June, 1941. In so far as this communication relates to three more recent notes on the mass of the meteorite responsible for the Canyon Diablo, Arizona, Meteorite Crater,[2] it is intended to justify objections to Wylie's results already expressed in private letters to him.

PART 1. *Contraterrene Meteorites*

Wylie's conjecture that a contraterrene meteorite would be annihilated almost instantly by "a single tremendous explosion high in the upper levels of the atmosphere" is based on the assumption that all of the energy developed in a (terrene proton-contraterrene proton)-annihilation would appear as *explosive energy* capable of doing mechanical work like that released by detonating nitroglycerin. This assumption appears to be entirely without foundation. Just as the kinetic energy of an ordinary meteorite is transformed by interaction between the swiftly moving meteorite, the air, and the ground into a wide variety of energy forms (*e.g.*, the radiant energy of meteoric luminescence, the acoustic energy of meteoritic detonations, the energy of ionization, of atmospheric wave-motion, of elastic ground waves, and, possibly, of crater-forming explosion), so the energy which would be developed in proton-annihilation would, without question, assume many forms, only one of which could legitimately be compared with the energy manifestation characteristic of exploding nitroglycerin. In the absence of a quantitative theory of the interaction between terrene and contraterrene matter, there can be no justification for asserting that all, or even that any large part, of the energy of annihilation *appears* in explosive form.

By analogy with the case of an (electron-positron)-annihilation, a far more probable assumption is that the energy of a (terrene proton-contraterrene proton)-annihilation would appear initially in the form of *radiant* energy, as I explicitly indicated in my original note on contraterrene meteorites.[3] In fact, Rojansky[4] does not hesitate to predict that at the instant of annihilation this energy would be shared between two *photons*, each of about one billion electron-volts. It may

be inferred (again by analogy with the familiar electron-positron case) that, ultimately, part of this radiant energy would be transformed into other types of energy; but, the *proportion* of the radiant energy so transformed and, above all, the *rate* at which such transformation would occur are entirely unknown and it must never be overlooked that the effectiveness of an explosive agency depends in large part on the *rate* at which explosive energy is liberated.[5] On the basis of analogy again, it is reasonable to infer from the magnitude of the attraction known to exist between closely juxtaposed electrons and positrons, that if a *macroscopic* mass of contraterrene meteorite were brought into such exceedingly intimate contact with the dense terrene material of the solid Earth as would occur during the forcible penetration of a meteorite into the terrestrial surface layers, then a rapid and continuous annihilation of matter on a large scale would be set up within a small and confined space. It seems reasonable, therefore, to suppose that under such circumstances enough of the radiant energy released would degenerate into the heat energy of molecular motion to give rise to a powerful explosion. But to assert that the same result would follow from the bombardment of a contraterrene meteorite by the relatively widely dispersed *molecules* of an exceedingly tenuous gas (the near vacuum of the upper atmosphere) is certainly without justification. On the one hand, the rate at which radiant energy would be developed by such a *molecular* bombardment would be relatively small, for the energy released by individual proton-proton-annihilations, altho large in comparison with other processes, is in actual magnitude quite insignificant (in fact, each proton-proton-annihilation would produce only 3.2×10^{-3} erg $= 7.6 \times 10^{-11}$ calorie). On the other hand, the *radiant* energy produced, *whatever its amount*, would not by itself exercise an explosive effect, and, under the near-vacuum conditions existing in the upper atmosphere, only a very small fraction of this radiant energy could possibly be expected to be transformed into heat (just as only a very small percentage of the solar radiant energy intercepted by the Earth is transformed into the heat energy of molecular motion in the upper levels of the atmosphere).

It is not the purpose of this note to prove that contraterrene meteorites exist. The writer has earlier pointed out that he suggested the possibility that certain craters were produced by contraterrene meteorites chiefly to silence those who insist that a crater cannot be of meteoritic origin unless meteorites are found associated with it.[6] Such insistence is clearly illogical unless proof can be given that contraterrene meteorites do *not* exist! No such proof has as yet been given. In fact, in the interval since my second note was published, several pieces of evidence supporting the hypothesis of the existence of contraterrene meteorites have come to my attention. We propose to conclude the first part of this paper by briefly mentioning one of the most interesting and striking examples of such evidence.

Anyone familiar with the nature of the so-called "instantaneous microatmosphere" which develops about an ordinary meteorite during its passage through the air will anticipate that a microatmosphere rich in contraterrene neutrons would develop about a contraterrene meteorite. Just as in the ordinary case, this microatmosphere would be constantly swept away and as constantly renewed. Therefore, the infall of contraterrene meteorites would be expected to be accompanied not only by annihilation of contraterrene matter but also by release in the atmosphere of numerous contraterrene neutrons. Now, as Rojansky has pointed out, the known existence of non-ionizing particles which release mesons well below

the top of the atmosphere can be satisfactorily explained by assuming that contraterrene neutrons set free in the earlier stages of the annihilation of contraterrene atoms by the air endure actually until they have penetrated deep into the atmosphere. Incidentally, with Rojansky's suggestion and the infinitesimally small mass of a contraterrene neutron (1.6×10^{-24} gram) in mind, we can better appraise the degree of confidence to be accorded to Wylie's conjecture that a contraterrene meteorite as massive as the giant Cape York, Greenland, siderite would be annihilated almost instantly high in the upper levels of the atmosphere.

Part 2. *The Probable Mass of the Canyon Diablo Meteorite*

In a series of recently published notes,[7] Wylie has given several calculations of the probable mass of the meteorite whose impact produced the great crater at Canyon Diablo, Arizona. The procedure employed is to compare the volume of the meteorite crater with the volumes of ordinary mine craters, either *directly* by use of specific mine craters such as the one blown by the British in Hill No. 60 near Ypres or *indirectly* by use of empirical mine-crater formulas such as that of Wessman and Rose. From volume comparisons, the quantity, Q, of nitroglycerin which, by its explosion under conditions as favorable as those realized in mining practice, would produce a crater of the size of that at Canyon Diablo is calculated. Depending on the data and method employed, the computed values of Q range between the wide limits of 2200 tons and 125,000 tons. If now, E denotes the total heat energy liberated by the detonation of Q tons of nitroglycerin and if m and v denote, respectively, the striking mass and the striking velocity of the Canyon Diablo meteorite, then Wylie's procedure amounts to assuming that, when expressed in the same units, E is equal to the kinetic energy, $\frac{1}{2}mv^2$. Under the hypothesis that the Canyon Diablo meteorite had a spherical shape, the resulting equation,

$$E = \tfrac{1}{2}mv^2, \tag{1}$$

is then solved for the mass, m, corresponding to various assigned values of the velocity, v.

The method of estimating m outlined in the last paragraph is open to a far more serious objection than any of those raised by members of the American Astronomical Society and considered in Wylie's second note on the Canyon Diablo Crater.[8] To use the volumes of the craters blasted out of the Earth as the *sole* basis for a comparison of the *striking kinetic energy* of a meteorite and the *potential* of a charge of nitroglycerin is a quite illegitimate procedure; indeed, it amounts to assuming that if f is the fraction of the kinetic energy of an impinging meteorite manifesting itself in crater excavation and if f' is the fraction of the *potential* of a properly set charge of nitroglycerin (one of the most efficient known blasting agencies) similarly manifesting itself, then $f = f'$. Such an assumption is entirely unacceptable to anyone familiar with the phenomena which accompanied the fall of the Podkamennaya Tunguska, Siberia, meteorite on 1908 June 30. In the case of this Siberian fall, energy equal to a considerable part of the total kinetic energy of the meteorite appeared in forms incapable of crater excavation, *e.g.*, as *radiant energy*. Obviously, if the same partition of energy were observed in the case of the explosion of a properly set charge of nitroglycerin, the sapper's art would be in a poor way! Actually, most of the energy released by such a charge manifests itself by doing useful (excavative) work. On the contrary, immediately after first contact between a meteorite and the

Earth, when *the rate of transformation of kinetic energy is a maximum*, the striking energy of the meteorite is acting *not* to upheave ground layers and blast out a crater, but (like the energy of a high-speed AP shot attacking armor plate) to set up a shearing stress exceeding the strength of the material in the target attacked. The action of the impinging meteorite is, therefore, analogous to that of a punch in a hyper-speed punch press, and most of the energy it expends on the Earth body-proper goes into the development of the shearing stresses and compressions which accompany its forcible penetration into the Earth. Only after a considerable depth of penetration has been attained, do conditions favorable for what can properly be termed an "explosion" develop. The energy released in this subterranean explosion, judged by normal standards, may be very great, but in comparison with other forms of work done by the meteorite, it is relatively unimportant. This latter fact becomes apparent if we apply Wylie's method to calculate the "striking kinetic energy" of the Podkamennaya Tunguska fall solely on the basis of the volumes of the craters formed, each crater being regarded simply as an "explosion crater" such as is produced by the detonation of a properly set charge of nitroglycerin. According to L. J. Spencer,[9] who seems to have received his information in a letter from L. A. Kulik, the craters resulting from the Siberian fall consist of " . . . numerous round depressions—10 according to some accounts and 200 according to another—ranging in diameter from 10 to 50 meters and up to 4 meters in depth." The writer, on the basis of his acquaintance with original Russian accounts of the Podkamennaya Tunguska fall, is convinced that we shall certainly *over*estimate the *total volume* of the Siberian "explosion craters" if we regard it as equivalent to that of 105 craters each having a diameter of $2r = 30$ meters and a depth of $h = 2$ meters (the averages of the numbers and dimensions given by Spencer). If we now write E for the number of ergs of energy expended in blasting out the Canyon Diablo Crater, for which $R = 2000$ feet and $H = 600$ feet (according to Wylie's most generous estimate, $E = 9 \times 10^{21}$ ergs), and let e denote the number of ergs of work done in excavating one of the 105 Siberian craters, then

$$e/E = r^2h/R^2H. \tag{2}$$

On solving for e and substituting numerical values, we find that $105e$ is about 6.3×10^{18} ergs. This is a smaller amount of energy than Whipple found was carried merely by the *air waves* created by the Siberian fall and represents between only 1/20 and 1/200 of the total "striking kinetic energy" of this fall as determined by Astapowitsch,[10] using several independent criteria.

If the same sort of energy-partition held in the case of the Canyon Diablo fall, then Wylie's estimate of a mass of 20,000 tons must be revised upward to between 400,000 and 4,000,000 tons. The *larger* of these two values has already been suggested by Öpik[11] as the probable mass of the Canyon Diablo meteorite on the basis of concordant results obtained by two different methods, the first based on the penetration observed at Canyon Diablo and the second on the total mass of rock crushed and dislocated at the Arizona Meteorite Crater. Öpik has given also a third method which, however, suffices to determine only a *lower bound* for the mass of the Canyon Diablo meteorite. This third method, altho it makes no use of "equivalent charges" of nitroglycerin, is closely related to that used by Wylie to determine, not a lower bound for the mass, but the mass itself, for Öpik's procedure is to set the striking kinetic energy of the Canyon Diablo meteorite equal to the mechanical work done in excavating the crater.

It is interesting to note that in the case of an impact velocity of 12 miles per second (the highest considered by Wylie), the *lower bound* for the mass, *m*, provided by Öpik's third method, altho it is more than a dozen times as large as the value 4,900 tons, computed for the mass, *m, itself,* by Wylie, is still about only 1/80 of the value for *m* found by use of Öpik's more exact methods. In this case, therefore, the "nitroglycerin method" fails even more completely than in the Siberian case to give any trustworthy indication of the mass of the meteorite in question.

NOTES

[1] Wylie, C. C., *P. A.*, **49**, 381, 1941.
[2] Wylie, C. C., *P. A.*, **51**, 97, 158, 220, 1943.
[3] La Paz, L., *C.S.R.M.*, **2**, 244; *P. A.*, **49**, 99, 1941.
[4] Rojansky, V., *Astroph. Jour.*, **91**, 258, 1940.
[5] *Cf., e.g.,* Davis, T. L., *The Chemistry of Powder and Explosives,* **1**, 23, 1941.
[6] La Paz, L., *C.S.R.M.*, **2**, 278; *P. A.*, **49**, 265, 1941.
[7] See note (2), *ante.*
[8] See note (2), *ante,* second reference.
[9] Spencer, L. J., *Geog. Jour.*, **81**, 235, 1933.
[10] *Cf.* Table 16 (p. 222 or p. 502) in the translation of I. S. Astapowitsch's 1933 paper on the Tungus meteorite, prepared by L. La Paz and G. Wiens and published in *C.S.R.M.*, **2**, 203-26; *P. A.*, **48**, 433-43, 493-506, 1940.
[11] Öpik, E., *Tartu Publ.*, **28**, No. 6, 1936.

VARIABLE STARS

Variable Star Notes from the American Association of Variable Star Observers

By LEON CAMPBELL, Recorder

Light Curves of Long-Period Variables: The Recorder has just completed the derivation of the mean light curves of 386 variable stars of long period, a task which was begun a year and a half ago and which involved the use of 600,000 visual estimates, most of them having been made by members of the American Association of Variable Star Observers.

This seemingly herculean task was made possible by the use of 10-day-mean ledgers which have been maintained at headquarters since 1922; in other words the curves include observations made over an interval of twenty years.

These notes for 1942 contain some of the preliminary information and the light curves for 100 of the variables. The light curves are more or less typical of the total of nearly 400 derived; they exhibit a diversity of shapes, from those with wide maximum and narrow minimum, through sine-like forms, to curves with very steep ascent to narrow maximum and slow descent to long flat minimum.

While most of the variables are of the Me spectral type, about five per cent are of the allied type, Se. There are three variables of type R, and 15 of type N. Many of the stars for which no spectral type has been observed doubtless can be considered as Me, when light curves and amplitudes are taken into account.

Mean intensity curves have also been derived for each of these stars. It has

been the hope that a study of both types of curves might reveal some correlations hitherto unsuspected, since the intensity curve might be more specifically influenced by the physical conditions which pertain in the stars.

Besides the derivations of light and intensity curves, there has been the opportunity for testing the mean periods over this twenty-year interval. The agreement with the periods derived for a much longer interval of years, as was done, for example in *Harvard Annals* 105, is, in general, exceedingly close. Over 16,000 dates of maxima and minima have been redetermined on a uniform basis for these nearly 400 stars, with periods from around 100 days to those of over 600 days.

It is planned to publish these light curves and related discussions in a forthcoming volume of the *Harvard Annals,* which, it is hoped, will serve as a further tribute to the worthwhile efforts of the amateur variable star observer.

At this point the Recorder desires to state very emphatically that the discussion of these long-period variables could not have been possible without the invaluable aid of the amateur variable star observer, not only from the ranks of the A.A.V.S.O., but also from the British, French, Australian, and New Zealand organizations.

Recent Maximum of U Geminorum: The recent maximum of U Geminorum was observed by many alert variable star observers—from New Hampshire to Mexico; from Maine to California. The star was rising rapidly on April 23 and remained bright for a week—a wide maximum.

The last observed maximum was that of September, 1942; also a wide maximum. The narrow maximum which usually occurs between two wide maxima was evidently of too short duration to be caught by the observers, if it occurred at all.

Nova Puppis: The Nova which appeared so suddenly in Puppis last November has passed from view for northern observers. Southern observers should be able to follow its light variations for a few weeks more. Observers are urged to keep a sharp watch on the nova when it appears in the eastern sky next fall. Anything might happen to the star during the next few months.

By a recent vote of the Council of the A.A.V.S.O. the David B. Pickering Nova Medal has been awarded to Professor Bernhard H. Dawson of La Plata, Argentina, as the original discoverer, by visual methods, of this most recent brilliant nova. The medal will be presented to Dr. Dawson at a formal meeting of the "Amigos de la Astronomia" at Buenos Aires by the American Ambassador to Argentina through the office of the United States Department of State. Although the David B. Pickering Nova Medal has been awarded to three previous discoverers of bright novae, Dr. Dawson is the first member of the A.A.V.S.O. to be so honored. This all goes to show that bright naked-eye novae do continue to appear—suddenly to be sure—and that the keen-eyed and star-minded observer can detect such new stars with exceeding promptness. Thus the A.A.V.S.O. Nova-search program may, after all, prove itself worthwhile. Plenty of patience is the main requirement. We must not forget, however, that such novae can be, and have been, detected by the merest accident notwithstanding the less successful diligent search by others.

Observers: In spite of poor weather conditions and the calling of many observers to the colors, a total of 36 observers with 2215 observations to their credit

speaks well for the interest still displayed in variable star observing. Comparatively few stars can be said to have been totally neglected, and the special irregular variables have come in for a fair share of observing attention. The list of observers and number of observations received during April follows:

Observer	Vars.	Obs.	Observer	Vars.	Obs.
Bappu	34	127	Manlin	18	18
Blunck	19	22	Maupomé, A. S.	60	67
Boone	21	21	Mayall	1	6
Bouton	49	79	Meek	25	87
Buckstaff	6	12	Moore	17	18
Cousins	22	48	Nadeau	52	70
Duffie	15	17	Parker	31	35
Fernald	205	334	Parks	24	34
Garneau	3	3	Peltier	141	213
Halbach	1	1	Rosebrugh	12	69
Harris	24	24	Sandage	7	32
Hartmann	102	178	Schoenke	18	26
Hiett	12	25	Segers	8	65
Howarth	15	18	Sill	27	27
Kearons	73	158	Vohman	18	20
Kelly	10	11	Webb	12	12
de Kock	47	192	Weber	47	47
Koons	63	91	—		—
Labrecque	7	8	36	Totals	2215

May 17, 1943.

Communications and Comments

Under this heading we shall publish from time to time such material as does not properly fall under any of the established headings of this journal. Here, too, may be found, when occasion arises, articles which the editor may not be willing to give sanction to but which, nevertheless, may be provocative of thought along new lines.

Science Comes to Earth

Hitler believes that his destiny is governed by the stars. British scientists are using the stars to hasten his destiny. But it is not the myths of the Zodiac, but the study of astrophysics that they are turning against him.

The other day I met a professor whom I had not seen since, years ago, I crawled, bewildered, out of an argument which he was having on the Theory of the Expanding Universe with Abbe Lemaitre, Sir Arthur Eddington, and Sir James Jeans. I asked him, jokingly, how the universe was behaving in wartime. "How should I know," he said, "I am working not on the expansion of the universe, but on the expansion of gases." He is one of our greatest experts on explosives.

This set me enquiring as to what had happened to Britain's mathematicians and astronomers. As I checked them off, one by one, I found that they were each of them making war in a forthright fashion. One, who used to be my guide to the Theory of Relativity and who made Space-Time comprehensible to me, is now working on the aero-dynamics of fighters and bombers. He hopes to produce a super-bomber which he wants to call "Einstein" to drop "Space-Time" bombs on Berlin where they burned Einstein's books.

Britain's astrophysicists, with their training in highly complicated calculations, have been invaluable in the study of explosives, the characteristics of blast, which were barely understood before the war, and the expansion of gases in general. They are studying now, not the behaviour of the stars in the universe, but the behaviour of atoms and electrons as instruments of war.

British astronomers have abandoned their telescopes, except for practical astronomy, such as the preparation of naval almanacs, and the briefing of the tank corps in the uncharted wastes of the desert. They are now among the greatest experts on ballistics. With their training in the measurement of deviation, necessary for their astronomical calculations, they are giving accuracy to Britain's long-range gunners and to the anti-aircraft barrage.

This is the hey-day of the scientists in Britain. No longer are they regarded as hermits shut away in their cells practicing knowledge for the sake of knowledge; they are in key positions everywhere in the fighting services. With their complete objectivity, their scientific disinterestedness and the discipline of their training, they are guiding, and in many ways dictating the naval, military, and air tactics of this war. They have worked out the Theory of Combat in the various types of operations.

Their maximum accuracy is in the air, in spite of three-dimensional fighting. When one hears of a thousand-plane raid being packed into fifty-five minutes over a single town in Germany, one should remember not only the vast ground organization, the transport supplies, the loading of the bombs, the timing of the take-off and returns, but also the intensive work of the scientists behind the operation.

They also work out in advance the mathematics of naval engagements, and one of the greatest of Britain's young scientists is now patrolling the seas calculating the co-efficients of convoys. He is one of the brains behind the Battle of the Atlantic and the shepherding of ships to Murmansk. That may seem remote from the atomic physics on which he was engaged before the war.

In addition to the scientific directors and advisers of the various services and supply agencies, Britain has now assembled a group of its most eminent scientists who, with complete independence, can examine the problems of any Ministry or department of government, plan more efficient organization, or install, in key points, scientific experts to ensure that efficiency. It is they who see that scientists are properly allocated.

Then there are scientists whose job it is to examine the inventions and suggestions which are sent in by ingenious amateurs amongst the British public. Out of the tens of thousands which have come in during the war, many have been of first-class importance, but even then the inventor may never know until after the war that he was the genius behind some new war development, due to the necessity for secrecy and security.

All that the inventor can be told is that his idea is being considered; if he were told it has been adopted, careless talk might warn the Germans what was being undertaken. For the same reason, he obviously cannot be told "Your idea is a good one, but we are already doing it."

One of the most popular discarded suggestions was that the atmosphere should be flooded with carborundum powder which would be sucked into the fascist aero-engines and chew them to pieces. It is difficult to convince people that there is an awful lot of atmosphere!

Another one was that they should spread throughout the atmosphere "a gas"

(unknown to the suggestor—to be discovered by the chemist) which would congeal round the plane in flight, and when the crew baled out, would wrap itself round them so that they would arrive on the ground like chickens in gelatine. This was the solution of the paratroop problem!

In spite of such amusing and unpractical suggestions, the British man-in-the-street has contributed many important new scientific ideas to the war. The ordinary man and the most learned scientists are working together.

As my friend the professor of astrophysics said, "British scientists have come down to Earth."

RITCHIE CALDER.

General Notes

Subscribers are reminded that there is no issue of this magazine scheduled for July. The next issue, the one for August, will appear about August 1. ED.

The honorary degree of Sc.D. of the University of Arizona has been conferred upon E. C. Slipher of the Lowell Observatory.—(*The Observatory*, April 1943.)

The Gold Medal of the Royal Astronomical Society has been awarded to the Astronomer Royal, Dr. H. Spencer Jones, F. F. S., for his determination of the solar parallax from observations of Eros in 1931.—(*The Observatory*, April, 1943.)

Correction.—On page 237 of the current volume of Popular Astronomy, line 19 from the bottom, the word "inversely" should be deleted.—O. STRUVE.

Book Reviews

The Story of the Moon, by Clyde Fisher. xiv—301 pp. (Garden City, N. Y.; Doubleday, Doran & Co., Inc., February, 1943. $3.00.)

To many American astronomers, Clyde Fisher is best known as the man who introduced them to the marvels of the Zeiss planetarium, as a result of his studies of that device in Europe several years before the Adler Planetarium opened in 1930. But also he is well known as a student of meteor craters. Probably he has studied, by personal visits, more of these remarkable objects than any other scientist. Since these craters seem to be the terrestrial features which most nearly correspond to lunar craters, it is not surprising that he has also long been interested in the Moon.

Though Dr. Fisher retired several years ago as the head of the Hayden Planetarium of the American Museum of Natural History, he has continued an active career of lecturing and writing. This well-illustrated book is one result. After an account of early lunar observations, he discusses the Moon's possible origin, concluding that "all the theories seem definitely hypothetical." Then comes a discussion of the Moon's motions, explaining the difficulty of an exact solution

of this problem, to which the late Professor Ernest W. Brown contributed so much. The Moon as a celestial body and its connection with tides are subjects which occupy chapters.

Chapter VI, "The Surface of the Moon," leads appropriately into one on the origin of the craters. Rejecting the bubble hypothesis he compares very judicially the volcanic and meteoric theories. Though he admits that "there is no certainty about the origin of the craters . . . and it should be kept in mind that there could have been more than one origin," he finally concludes that "most of the evidence is in favor of the impact theory, bearing in mind that the important part of the phenomenon in crater formation is the explosion caused by the impact." This opinion is supported by the study of the terrestrial meteor craters which are, particularly in the case of those in Arizona and Estonia, described in detail.

Briefly considering possible life on the Moon (and deciding against it) Dr. Fisher then comes to two chapters on eclipses, one of which recounts his personal experiences. Of very general interest is the chapter on myths, mistakes (like the Ancient Mariner's "one bright star within the nether tip"), and lunar folklore, of which there is a great deal, stemming from many different races. The final chapter tells of the 27 other satellites in the Solar System.

"The Story of the Moon" was written for a popular audience, and by an author with long experience in presenting astronomy to laymen. But Dr. Fisher has gathered here so much information about our satellite, a great deal of it otherwise available only in very scattered sources, that this will be a useful addition to the library of any observatory, professional or amateur. Even a person who is not particularly interested in astronomy, on the other hand, would probably be able to enjoy it. Moon lore has so many aspects that it should interest any intelligent person with a curiosity about his universe.

JAMES STOKLEY.

Research Laboratory, General Electric Co., Schenectady, N. Y.

1943, May 11.

A Start in Meteorology by Armand N. Spitz and **Air Navigation for Beginners** by Scott G. Lamb are two small volumes of about 100 pages each published by the Norman W. Henley Publishing Co. of New York at $1.50 each. They are admirably planned to serve as brief introductions to their respective fields. Any high school student could read with profit. The one objection in the mind of the reviewer is the price. E.A.F.

Weather, An Introductory Meteorology by W. G. Kendrew, 96 pp. Oxford University Press. $1.00. The reviewer cannot be certain but this book seems to be a resumé of a more extensive volume on the same subject. It is very well written from this standpoint and could be profitably read by some one preparing for a an examination in the elements of meteorology. E.A.F.